Understanding resilience in collaborative projects

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DOCTORAL THESIS

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Abstract

Nowadays, most organizations conduct their innovation efforts through interorganizational collaborations. The goal of this innovation strategy is to access external resources, share costs and risks, and ultimately enhance innovation processes. These endeavours are typically implemented through projects, often referred as collaborative projects. Despite the growing interest of both private and public sectors in fostering innovation through collaborative projects, many of them struggle to achieve their objectives concerning the triple constraint and / or stakeholder´s satisfaction.

Bringing together actors from diverse knowledge fields, industries, and cultures offers a fertile ground for the development of innovative products, services, and technologies. However, this collaborative context also presents significant managerial challenges for project partners, owing to the complexity, ambiguity, and uncertainty inherent in these projects. In this context, effectively managing disruptions arising from unforeseen threats becomes significant, as project´s failure becomes a likely outcome without proper response and adaptation to them.

In this vein, the objective of this study is to increase the current understanding about how collaborative projects overcome perturbations, focused on the dynamic interplay between three significant constructs during perturbations: equivocality, governance and organizational learning. Equivocality is a central issue in a network of partners and it is exacerbated during perturbations. Changes in governance approaches do not only might contribute to overcome perturbations, but also these might exacerbate or reduce equivocality levels. As the partners have no previous experience of dealing with a disruption, they must react and apply their learning capabilities to overcome it. These three constructs represent fundamental aspects to deal with during perturbations, whose interrelationships are better explained by mutual causality and non-linearity.

The research framework applied is rooted in the complexity theory, with a specific emphasis on the concepts of complex adaptive and generative systems. A cross-case analysis based on a single and successful collaborative project, the LOCUTIOS project was conducted. This project was embedded in a high uncertain environment, being able to overcome two instances of perturbations and still delivering valuable outputs and outcomes. In this sense, abductive approaches were used as a reasoning logic. Cross-case analysis was applied to investigate corresponding responses that facilitated resolution and ensured resilience, based on the interrelationships between the three constructs.

The research's contribution is summarized through a framework that offers explanations into how this successful case managed to overcome perturbations. The framework contributes to explain two

different reaction patterns, characterised by different learning behaviours (adaptive or generative), governance approaches (complementarity or substitution), and role of equivocality (driver or barrier) to knowledge exploration. Achieving resilience does not follow a unique path; instead, there are (at least) two approaches distinguished by the learning behaviours of the organizations, namely generative and adaptive resilience that enable a project to overcome perturbations. The relevance of this research resides on explaining various forms of potential resilience within collaborative projects when confronted with unforeseen challenges, filling a gap in the literature.

Resumen ejecutivo.

En la actualidad, la mayoría de las organizaciones ejecutan la innovación a través de colaboraciones con otras organizaciones. El objetivo de esta estrategia es acceder a recursos externos, compartir costos y riesgos para mejorar los procesos de innovación en última instancia. Estas acciones se llevan a cabo a través de proyectos, usualmente denominados proyectos colaborativos. A pesar del creciente interés tanto del sector privado como del público en fomentar la innovación a través estos proyectos, muchos de ellos encuentran serios desafíos para alcanzar sus objetivos en relación al tiempo, coste, alcance (triple restricción) y/o la satisfacción de los interesados.

El hecho de reunir a actores de diversos campos de conocimiento, industrias y culturas ofrece un terreno fértil para el desarrollo de productos, servicios y tecnologías innovadoras. Sin embargo, este contexto también presenta desafíos significativos de gestión para los participantes, debido a la elevada complejidad, ambigüedad e incertidumbre, inherentes a estos proyectos. En este contexto, se torna relevante la gestión efectiva de las perturbaciones / disrupciones que emergen como resultado de situaciones imprevistas. El fracaso del proyecto se convierte en un resultado probable cuando las perturbaciones y la respuesta a ellas, no se gestionan de una manera adecuada.

En este sentido, el objetivo de este trabajo es aumentar el conocimiento actual sobre cómo los proyectos colaborativos superan las perturbaciones, centrándose en la interacción dinámica entre tres constructos: la equivocalidad, la gobernanza y el aprendizaje organizacional. La equivocalidad es un problema central entre los participantes y sus efectos se agravan durante las perturbaciones. Los cambios en la gobernanza del proyecto no solo permiten superar las perturbaciones, sino que también pueden exacerbar o reducir los niveles de equivocalidad. Dado que los socios pueden no contar con la experiencia y el conocimiento previo para sobreponerse a una disrupción, al enfrentarse a ella, estos deben reaccionar y aplicar sus capacidades de aprendizaje para poder superarla. Estos tres constructos representan aspectos fundamentales a tratar durante las perturbaciones, cuyas interrelaciones se explican mejor mediante causalidad mutua y no linealidad.

El marco de investigación aplicado se basa en la teoría de la complejidad, con énfasis específico en los conceptos de sistemas complejos adaptativos y generativos. Se llevó a cabo un análisis cruzado de casos, basado en un proyecto colaborativo exitoso, el proyecto LOCUTIOS. Este proyecto se desarrolló en un entorno de alta incertidumbre y fue capaz de superar dos instancias de perturbación y, aun así, entregar resultados valiosos para los interesados. Se utilizaron enfoques abductivos como lógica de razonamiento. El análisis de casos cruzados se aplicó para investigar las respuestas correspondientes que facilitaron la resolución de las dos perturbaciones y permitieron la resiliencia del proyecto, basándose en las interrelaciones entre los tres constructos.

La contribución de la investigación se resume en un modelo que ofrece explicaciones sobre cómo en el caso de estudio se logró superar las perturbaciones. El modelo contribuye a explicar dos patrones de reacción diferentes, caracterizados por diferentes comportamientos de aprendizaje (adaptativo o generativo), enfoques de gobernanza (complementariedad o sustitución) y el papel de la equivocalidad (generador o barrera) en la exploración del conocimiento. Ser resiliente no es un proceso que sigue un camino único; en su lugar, existen (al menos) dos maneras distintas, caracterizadas por el aprendizaje organizacional, a saber, la resiliencia generativa y adaptativa, que permiten que un proyecto supere las perturbaciones. La relevancia de esta investigación radica en explicar diversas formas de resiliencia potencial dentro de proyectos colaborativos cuando se enfrentan a desafíos imprevistos, contribuyendo con una aportación a un aspecto relevante pero poco estudiado en la literatura.

Resum

Actualment, la majoria de les organitzacions porten a terme els seus esforços d'innovació mitjançant col·laboracions interorganizacionals. L'objectiu d'aquesta estratègia d'innovació és accedir a recursos externs, compartir costos i riscos, i, en última instància, millorar els processos d'innovació. Aquests esforços sovint es duen a terme a través de projectes, anomenats projectes col·laboratius. Malgrat l'interès creixent tant del sector privat com del públic en fomentar la innovació mitjançant projectes col·laboratius, molts d'ells lluiten per assolir els seus objectius relacionats amb la triple restricció i/o la satisfacció de les parts interessades.

Reunir actors de diversos camps de coneixement, indústries i cultures ofereix un terreny fèrtil per al desenvolupament de productes, serveis i tecnologies innovadores. No obstant això, aquest context col·laboratiu també presenta reptes de gestió significatius per als socis del projecte, a causa de la complexitat, l'ambigüitat i la incertesa inherents a aquests projectes. En aquest context, gestionar de manera efectiva les interrupcions que es deriven d'amenaces imprevistes esdevé significatiu, ja que el fracàs del projecte es converteix en un resultat probable sense una resposta i adaptació adequades.

En aquest sentit, l'objectiu d'aquest estudi és augmentar la comprensió actual sobre com els projectes col·laboratius superen les pertorbacions, centrant-se en la interacció dinàmica entre tres constructes significatives durant les pertorbacions: l'equivocitat, la governança i l'aprenentatge organitzatiu. L'equivocitat és una qüestió central en una xarxa de socis i s'exacerba durant les pertorbacions. Canvis en els enfocaments de la governança no només podrien contribuir a superar les pertorbacions, sinó que també podrien exacerbar o reduir els nivells d'equivocitat. Ja que els socis no tenen experiència prèvia en el tractament d'una interrupció, han de reaccionar i aplicar les seves capacitats d'aprenentatge per superar-la. Aquestes tres constructes representen aspectes fonamentals a tractar durant les pertorbacions, les interrelacions de les quals s'expliquen millor mitjançant causalitat mútua i no linealitat.

El marc de recerca aplicat es basa en la teoria de la complexitat, amb un èmfasi específic en els conceptes de sistemes complexos adaptatius i generatius. Es va dur a terme un anàlisi de casos creuats basat en un exitós projecte col·laboratiu, el projecte LOCUTIOS. Aquest projecte es va desenvolupar en un entorn d'alta incertesa, aconseguint superar dues instàncies de pertorbacions i continuant aportant resultats valuosos. En aquest sentit, es va utilitzar un enfocament abductiu com a lògica de raonament. Es va aplicar l'anàlisi de casos creuats per investigar les respostes corresponents que facilitaven la resolució i asseguraven la resiliència, basant-se en les interrelacions entre els tres constructes.

La contribució de la recerca es resumeix mitjançant un marc que ofereix explicacions sobre com aquest cas d'èxit va aconseguir superar les pertorbacions. El marc contribueix a explicar dos diferents patrons de reacció, caracteritzats per diferents comportaments d'aprenentatge (adaptatiu o generatiu), enfocaments de governança (complementarietat o substitució) i el paper de l'equívocitat (motor o barrera) en l'exploració del coneixement. Aconseguir la resiliència no segueix un camí únic; en comptes d'això, hi ha (com a mínim) dues aproximacions que es distingeixen pels comportaments d'aprenentatge de les organitzacions, a saber, la resiliència generativa i adaptativa que permeten que un projecte superi les pertorbacions. La rellevància d'aquesta recerca rau en explicar diferents formes de resiliència potencial dins de projectes col·laboratius quan s'enfronten a reptes imprevistos, omplint un buit a la literatura.

Introduction.

Research background.

Modern organizations conduct most of their innovation efforts through inter-organizational collaborations (Klessova, Engell, & Thomas, 2023; Malherbe, 2022; vom Brocke & Lippe, 2015). In the new century, there has been a notable shift among companies towards adopting a networked approach, expanding their boundaries to foster innovation (Derakhshan, Fernandes, & Mancini, 2020; von Danwitz, 2018). Establishing collaborations among companies is not only restricted to private organizations (Gassmann, Enkel, & Chesbrough, 2010). Public agencies such as governments or international communities are also encouraging innovation by funding collaboration agreements among the private sector, governments and universities (Calamel, Defélix, Picq, & Retour, 2011; Fernandes, Dooley, David O'Sullivan, & Rolstadås, 2021). The rationale behind this approach to innovation is to gain access to valuable external resources and knowledge, share costs and risks, and ultimately improve the effectiveness of their innovation processes (Gama, Sjödin, & Frishammar, 2017; Gassmann et al., 2010). There is ample evidence supporting the idea that organizations that open their boundaries to foster innovation efforts are more effective and generate greater value than those relying exclusively on internal resources (Du, Leten, & Vanhaverbeke, 2014).

In the literature, collaboration between different organizations has predominantly emphasized the ecosystem/network level (Gulati, Wohlgezogen, & Zhelyazkov, 2012; Manning, 2017), where organizations participate in collaborative programs without explicit time constraints (Sydow & Braun, 2018). However, the implementation of collaborative intentions is executed through projects, commonly known as interorganizational projects (Jones & Lichtenstein, 2008) or collaborative innovation projects (Marcandella & Guèye, 2018). Despite of the increasing interest of the private and public sector on fostering innovation through the development of collaborative projects, many of them fail to meet their objectives in terms of triple constraint or stakeholder´s satisfaction (Fernandes et al., 2021; Malherbe, 2022; Michelfelder & Kratzer, 2013; Nisula, Blomqvist, Bergman, & Yrjölä, 2022; vom Brocke & Lippe, 2015).

On the one hand, bringing together actors from different knowledge fields, industries, and cultures provides a rich environment for the development of innovative products, services, and technologies (Nisula et al., 2022; vom Brocke & Lippe, 2015). On the other hand, this collaborative environment presents significant managerial challenges for the partners involved in the projects (Derakhshan et al., 2020; Eriksson, Patel, Sjödin, Frishammar, & Parida, 2016). The presence of diverse knowledge backgrounds, working methodologies, and interests creates a complex and uncertain environment aimed at developing novel and innovative output (Eriksson et al., 2016; Klessova, Engell, & Thomas,

2022), introducing higher levels of uncertainty, complexity, and ambiguity into the project (Burström & Wilson, 2018). These challenges significantly impact the project's ability to deliver valuable outcomes and achieve ambitious cost and time objectives, seriously affecting its likelihood of success.

Research relevance.

Significant investments of time and resources have been made and continue to increase in the development of collaborative projects (Derakhshan et al., 2020). An example of this is the European Commission, which has allocated nearly 40 billion euros to the H2020 Programme, aimed at fostering innovation, collaboration, and competitiveness (Klessova et al., 2022). The COVID-19 has even boosted the need of collaboration between university, industry, public agencies and the society (Fernandes et al., 2021), for instance, through the Next-generation EU programme in which is estimated to invest more than 1 trillion euros (European Commission). The promotion of innovation through collaboration is not limited to the European countries. Countries such as the United States, Japan, and South Korea are also actively pursuing public policies that encourage collaboration for innovation (Hemmert, Bstieler, & Okamuro, 2014). Arshed et al. (2021) show that the increase in the intensity of university-industry collaboration is positively associated with an increase in economic growth. This research is relevant as it improves our understanding of the success of collaborative projects, including its barriers and drivers, that involve substantial investments of money, time, and resources, despite their high failure rate (Fernandes et al., 2021).

How to develop successfully a project has been one of the main topics of discussion among researchers in the literature of project management (Padalkar & Gopinath, 2016; H. J. Smyth & Morris, 2007; Söderlund, 2011). Two different approaches coexist in the literature, such as project success under the perspective of “efficiency” or under the perspective of “value” (P. Daniel & Daniel, 2018; Laursen & Svejvig, 2016). The first one is a short-term orientation that considers how effective the project accomplishes the initial objectives regarding cost, time and scope/ quality (Cooke-davies, Crawford, & Lechler, 2009; Kapsali, 2011). The second one focuses on the long-term perspective, addressing the project's impact on the organization's outcomes and the value it adds to the stakeholders (Laursen & Svejvig, 2016). Assessing the project success based exclusively on the efficient development of project outputs is fundamentally different from evaluating it in terms of the value that outcomes bring to the stakeholders. While efficiency focuses on the timely and cost-effective delivery of project outputs, evaluating value considers the broader impact and benefits generated for the stakeholders.

As organizations continue to invest more in collaborative projects, which often experience higher failure rates compared to other types of projects (Fernandes et al. 2020), there is a promising, yet

underexplored research area focused on their success. Consequently, the scientific community is becoming increasingly interested in comprehending the factors and mechanisms that influence the success and failure of these projects (Klessova et al., 2022; Malherbe, 2022; Nisula et al., 2022). At this stage, the following research question drives this academic endeavour:

How does project´s success is achieved in collaborative projects?

Research problem.

Collaborative projects operate in a context characterized by the limited predictability capacity of managers, moving and unclear goals and collective decision-making (Calamel et al., 2011; Klessova, Thomas, & Engell, 2020). In this increasingly uncertain environment, effectively managing perturbations arising from unforeseen adversities become unavoidable (Fey & Kock, 2022; Yang, Wang, Zhu, & Müller, 2022). Such disturbances require the partners to respond, adjust, and stabilize the project; otherwise, project failure becomes a likely outcome (Yang et al., 2022). In this vein, the success of projects relies more on their capacity to navigate disruptions caused by unexpected events (Fey & Kock, 2022) rather than on accurate predictions of known potential events (Yang et al., 2022). In recent years, there is an increasing interest of the scientific community to shift the focus from mitigating known vulnerabilities (risk management) to overcoming unknown disruptions (Naderpajouh, Matinheikki, Keeys, Aldrich, & Linkov, 2020). In this context, the concept of resilience offers a deeper understanding of how teams can effectively overcome disturbances arising from "unknown unknowns," which are significant and inevitable in collaborative projects (Wied, Koch-Ørvad, Welo, & Oehmen, 2020).

Understanding the success of a collaborative project is a broad and multidimensional topic with implications in various fields, including uncertainty management, knowledge management, time management, strategy formulation, and governance practices, among others (Padalkar & Gopinath, 2016). This research focusses on understanding how a project is able to overcome perturbations and still develop outputs and deliver value to the stakeholders, being resilient. This topic is relevant to study because of the significant impact that overcoming perturbations has on a project's overall project success (Fey & Kock, 2022). Empirical studies, such as those conducted by Wied M. et al. (2020) and Fey & Kock (2022), have explored specific actions or behaviours to address unexpected disruptions. Based on a qualitative analysis of the approaches applied by project managers, Wied et al. (2020), have identified 11 generalizable actions related to prepare, react and response to perturbations in exploratory projects. Fey and Kock (2022) have demonstrated that innovation resilience behaviour is positively related with project success, and it is more critical when the impact

of the disruptions increase. However, new insights to better understand “how” a project overcomes perturbations remains necessary and reveals new research avenues (Naderpajouh et al., 2020).

Intended contribution.

This study aims to fill this gap by analysing the complex interrelationships between relevant constructs: equivocality and governance, and the moderating role played by organizational learning during perturbations (Eriksson et al., 2016; Solís-molina, Hernández-espallardo, & Rodríguez-orejuela, 2020). Equivocality refers to the presence of multiple and opposing interpretations of information, goals, tasks, and activities (Daft & Weick, 1984). The presence of a wide range of partners creates a context where each partner has the potential to interpret the same information differently. Additionally, the project´s responsibilities and decisions are shared collectively among partners, contrarily to buyer-supplier contracts (Calamel et al., 2011). Thus, aligning a broad diversity of backgrounds, interests and expectations becomes a challenging task, leading to situations of high equivocality (Burström & Wilson, 2018). In this sense, the implications of equivocality have a direct impact on the success of the project, and if they are not effectively mitigated, the project may fail to meet its objectives (Frishammar, Florén, & Wincent, 2011).

Governance in projects comprises the use of systems, agreements, structures of authority, actions, decisions and processes to allocate resources and to coordinate/control activities (Pinto, 2014). The governance structure in collaborative projects is designed to enhance the probability of project success, with its implementation or adaptation closely tied to the project's overall success (Choi & Contractor, 2019). In addition, the positive or negative implications of equivocality in project results are moderated by the governance approaches applied to manage them (Eriksson et al., 2016). Both governance and equivocality are relevant constructs in collaborative projects: governance relates to managerial aspects, while equivocality represents a key characteristic of heterogeneous partner networks (Brun, 2016). Changes in governance strategies produce equivocality and equivocality demands for the application or adaptation of governance approaches to deal with it during the project (Majchrzak, Jarvenpaa, & Bagherzadeh, 2015).

Organizational learning is a concept broadly studied in the literature of organizations, and it is defined as the process through which organizations change or modify rules, processes or knowledge, maintaining or improving their performance (Argyris, 1976). In collaborative projects, this capability is relevant because the project is developed by consortium of partners with a broad diversity of backgrounds, methodologies and interests, and probably no previous experiences working together (Davenport, Grimes, & Davies, 1996; Huikkola, Ylimäki, & Kohtamäki, 2013). According to the literature, there is a correlation between increased levels of organizational learning capabilities and

improved performance outcomes, underscoring the significance of this capability in attaining project success (Solís-Molina, Hernández-Espallardo, & Rodríguez-Orejuela, 2021).

The rationality behind the decision of choosing these three constructs is their significant relevance during perturbations. Managing equivocality is a central issue in a network of partners and it is exacerbated during perturbations, while governance might exacerbate or mitigate it. As the partners might have no previous experience of dealing with a disruption, they must react and apply learning capabilities to overcome it (Eriksson et al., 2016). In this sense, a refined research question that motivates this research endeavour is:

How do equivocality, governance, and interorganizational learning interplay together to overcome perturbations?

This research aims to study the mutual and complex interrelationships between these three constructs during the process of overcoming perturbations. The contributions are derived from a framework that enables a deeper understanding of different types of reactions to similar perturbations.

Research strategy.

This thesis is the culmination of a 5-year research program. During the first years, the objective was to provide clarity on the concept of success in collaborative projects and subsequently investigate the implications of equivocality, governance, and organizational learning in this context. This endeavour has helped to establish the foundational knowledge for this research. In the latter phase, spanning the last three years, the author focused on developing the scientific contribution of the research, resulting in a publication in a journal. As such, this thesis is divided into two sections, reflecting the progression of the research and its outcomes.

Part I. Understanding success in collaborative projects.

The project success is a widely researched subject within the field of project management (Padalkar & Gopinath, 2016; H. J. Smyth & Morris, 2007; Söderlund, 2011), and it is often approached from two contrasting perspectives: efficiency and value (P. Daniel & Daniel, 2018; Laursen & Svejvig, 2016). This section aims to shed light on how both perspectives operate in the context of collaborative projects, where the outcome is inherently difficult to predict upfront and relies on complex knowledge interactions among partners.

To enhance our understanding of this relatively unexplored phenomenon, a research framework is proposed, based on a comprehensive literature review. This initial framework aims to conceptualize the interplay between equivocality and governance and their implications (individually and collectively) into project results, measured either by efficiency or value paradigms. Grounded theory

is employed as the methodology to delve deeper into the subject. Through a series of open interviews with project managers involved in collaborative projects, the proposed framework is further improved and a deeper comprehension of the intricate reality of collaborative projects is gained. The collected data provides valuable insights that contributed to focus the research on concepts that have received limited attention: organizational learning and uncertainty in collaborative projects. These concepts serve as the foundation for the subsequent section, which specifically examines strategies to overcome disruptions (originated by the inherent uncertainty of collaborative projects), based on the mutual interrelationships between equivocality, governance and organizational learning.

Additionally, there have been enhancements to the boundary conditions of the research, shifting its focus from collaborative projects to particularly emphasize collaborative "research" or "exploratory" projects (Wied et al., 2020). Collaborative projects encompass a wide range of specific settings, contingent upon the maturity of the technology or knowledge developed, spanning from highly scientific endeavours to those closer to market application (Klessova et al., 2022). Both types of projects exhibit significantly different natures, as well as varying levels of uncertainty associated with their outcomes. Hence, this research concentrates on scientific /exploratory projects due to their increased likelihood of encountering disruptions stemming from their high uncertainty associated with their outcomes, goals, and context. Applicability and generalizability of the contributions developed in the part II are bounded to such typology of collaborative projects.

Part I encompasses chapters 1 through 6. Chapter 6 introduces the refined research model, which serves as the theoretical cornerstone for Part II, where the academic contribution is further elaborated.

Part II. Overcoming perturbations in collaborative research projects.

This section focuses on developing the scientific contribution of the research, by proving light into different manners to overcome perturbations in collaborative projects. Specifically, it aims to describe the complex and nonlinear relationships between three key constructs: equivocality, governance, and organizational learning, during perturbations caused by unknown unknowns. Recognizing the limitations of deterministic approaches in capturing and modelling these intricate relationships, complexity theory is employed as a research framework to provide a more appropriate and comprehensive approach. Complexity theory facilitates a deeper understanding and analysis of the mutual and non-lineal interactions that characterize these relationships during perturbations. Among the broad diversity of theories and models existing in the complexity theory field, we apply the concepts of complex adaptive and generative systems (Anderson, 1999; Chiva, Grandío, & Alegre,

2010), as frameworks to analyse the evolution of the dynamic interrelationships between the three constructs during perturbations.

The abductive approach is utilized as a methodological reasoning because it is suitable for providing plausible explanations for how or why (Saetre & Van de Ven, 2021) events occurred and for modelling this reality using previously theorized frameworks such as complex adaptive and generative systems (Chiva, Ghauri, & Alegre, 2014). A successful collaborative project, known as the LOCUTIOS project, was chosen as a sample for analysis. The case study is based in a cross-case analysis, examining two instances of perturbations and explored the corresponding reactions that facilitated their resolution. In the discussion, it is proposed a framework that capture different types of reactions to perturbations, according to the learning behaviour of the team, either adaptive or generative. This framework represents the novel contribution of the research, as it highlights two different manners of being resilient and overcoming perturbations in collaborative projects, as the result of the evolving relationships between equivocality, governance and organizational learning. This research aims to capture the complex reality of dealing with perturbations in collaborative projects and models the behaviour that enable a project to overcome them.

The result of this section is an article that has been published in the journal Project Leadership and Society (Nihoul, Miralles F, & Neamtu, 2023).

Research objectives.

The overall research goal is to contribute to the fields of project management and innovation studies by increasing the understanding of how project success is reached within the context of collaborative projects. For that purpose, a broad research question is proposed in the first section, to guide the research efforts:

Main question: *How does project´s success is achieved in collaborative projects?*

Subsequent questions:

1. What are the implications of equivocality in the project results and their success measures?
2. What role does governance play in managing equivocality within collaborative projects?
3. How does organizational learning contribute to the successful delivery of joint outputs and outcomes in collaborative projects?

However, as the author acquired a deeper understanding of the intricacies within collaborative projects, various research avenues emerged as potential areas for contribution. In this regard, the scientific contribution of this research is developed in part II, wherein a more precise research gap has been identified, resulting in a refinement of the initial research question:

Refined research question: *How do equivocality, governance, and interorganizational learning interplay together to overcome perturbations?*

The objective of this study is to increase the current understanding about how a collaborative project is able to overcome perturbations, focused on the dynamic interplay between equivocality, governance and organizational learning, being them highly significant in times of disruptions. This research develops a research framework that provides plausible explanations about how a successful case (LOCUTIOS project) was able to overcome two instances of perturbations and still delivering value to the stakeholders. The main findings show that, in both cases, the LOCUTIOS project was able to overcome perturbations, but following different dynamic behaviours, characterized by transcendence (Jantsch, 1980), and adaptation (Anderson, 1999), respectively. In this sense, two different patterns were identified to enable the resilience of a collaborative project. The main contribution of this work is to propose, following a complex system approach, sound schemas for collaborative projects to resiliently overcome perturbations.

During the first perturbation, equivocality acted as a driver for expansive learning and knowledge exploration, enabled by a complementarity between relational and formal approaches (characterized as enabler/compensator) and double loop learning processes. This system´s configuration enabled the project to overcome the perturbation by transcending its initial state. The outcomes associated with this behaviour include an enhancement in the quality of collaboration among the involved partners, reflected in joint outputs stemming from the collaboration between two different knowledge fields. In the second case, equivocality acted as a barrier for knowledge exploration, prompting knowledge exploitation processes that were better executed by formal governance implications. Formal and relational governance acted as substitutes (either / or) and these do not complement each other. Last, single loop learning was found as the predominant learning approach, leading to individual/ incremental knowledge outputs. This system´s configuration enabled the project to adapt when it faces a perturbation.

This research does not only provide novel academic contributions since it provides practical recommendations to project managers and team members involved in collaborative projects. These recommendations are closely tied to the research framework proposal, which emphasizes that perturbations can serve as both a catalyst for knowledge exploration and a further enhancement of the collaborative capacity among partners, or as barriers to mutual understanding, thereby reducing the partners' collaborative capacity and knowledge exploration. In both scenarios, the outcomes are contingent on different governance adaptation and organizational learning processes. This underscores how different learning processes, managerial actions, and equivocality situations influence a project's ability to navigate perturbations and the associated results.

Part I: Understanding project´s success in collaborative projects.

1. Introduction.

The concept of project´s success has been extensively studied within the project management field. Despite the longstanding interest of the scientific community in gaining a deeper understanding of the factors, conditions, and challenges that influence the project success, the discussion surrounding "*What constitutes project success?*" remains ongoing (Ika & Pinto, 2022). Indeed, the wide range of contexts in which projects operate (Bakker, 2010) contributes significantly to this ongoing debate. The success of a project is greatly influenced by the distinct characteristics and features that are inherent to different project typologies (Chiesa & Frattini, 2007). The first objective of this section is to elucidate what represents "success" in the context of collaborative projects.

Equivocality represents a greater challenge in the context of collaborative projects, acting as a double-edged sword (Eriksson et al., 2016). Its implications on project results, either positive or negative, are moderated by the governance approaches taken to deal with it (Brun, 2016). However, governance approaches might be also source of equivocality, or even exacerbate its implications on the project results (Morandi, 2013). This section also seeks to enhance clarity regarding the dynamic interplay between equivocality issues, governance approaches, and their impact on project results and their success measures. The significance of this research lies in recognizing equivocality and governance as crucial factors to manage in collaborative projects (Benítez-Ávila, Hartmann, Dewulf, & Henseler, 2018; Frishammar et al., 2011). Surprisingly, the relationship between these factors has been largely overlooked in the literature, despite its notable effects on project results.

This section is organized as follows. It begins with a literature review of the key concepts relevant to the research, starting with an in-depth description of the nature of collaborative projects, followed by the coexistence of two success perspectives, to end up with the interplay between equivocality, and governance. Then, the literature review culminates in the presentation of a framework that serves as a guiding framework for an exploratory study conducted with project managers and team members involved in collaborative projects. Subsequently, the methodology is detailed aimed to provide additional insights into the proposed framework through the incorporation of empirical findings. Given the exploratory nature of this section, it concludes with a discussion that aids in reframing the initial framework and narrowing down the research focus to a more specific context, such as the emergence of organizational learning and addressing uncertainty and their implication on the project success in collaborative research projects.

2. Literature review.

2.1 Subject of analysis: collaborative projects

For over six decades, project management (PM) has emerged as a well-established discipline, with dedicated communities of practitioners and widely accepted methodologies and standards like PMBOK® and PRINCE2® (Padalkar & Gopinath, 2016). These normative tools and techniques were initially developed in the construction and aerospace sectors, primarily to enhance scheduling management practices (Söderlund, 2004). Since the 1990s, the field has transitioned from being primarily practitioner-driven to becoming a recognized academic discipline (Sydow & Braun, 2018). This shift was prompted by an increase in research published in reputable management journals after the publication of the seminal work of Lundin and Söderholm (1995). Their work laid the foundation for project research studies by defining a project as a *"temporary organizational form"* which remains the most widely accepted definition (Jones & Lichtenstein, 2008; Sydow & Braun, 2018). They characterized a project following the 4T framework:

- Time: projects are distinct from permanent organizational settings because they are designed with a predefined termination mechanism, either a specific time or the finalization of an output.
- Team structures: Individuals collaborate either within a single organization or across multiple organizations.
- Task: projects are initiated to address specific objectives or tasks that are often unique and more complex compared to those encountered in permanent organizations.
- Transition: This refers to the transformation from the "before" state to the "after" state in project work, its outcomes, and how this is perceived by the project team and stakeholders.

In Bakker's (2010) literature review, he further proposed that *context* should be considered as an additional dimension, highlighting how temporary organizations are interconnected and integrated within various contextual settings. These settings may include operating within a permanent organization, forming alliances with other organizations, or being situated within a broader context. In this regard, this research aligns with the academic stream of project research, viewing a project *as a temporary organizational* form with the purpose of accomplishing a specific task through teamwork (Lundin & Söderholm, 1995). It recognizes that projects create a transition for stakeholders and are embedded within diverse contextual settings (Bakker, 2010).

In the context of project research multiple research lines coexist (Padalkar & Gopinath, 2016; Söderlund, 2011; Sydow & Braun, 2018). The work of Söderlund (2004) served as a foundation for categorizing these research lines based on the number of firms involved and the number of projects

undertaken by a firm or firms. He referred to projects developed by a single organization as "intra-firm projects" and projects involving more than one organization as "inter-firm projects" (Söderlund, 2004). Nowadays, the majority of projects are undertaken by multiple organizations, resulting in outputs and outcomes that are collectively co-created among the partners involved (von Danwitz, 2018). Despite the growing importance of inter-firm projects in the literature, project management research has been slower in conceptualizing the interorganizational aspects of projects (Sydow & Braun, 2018). In this sense, as most of the projects are developed by multiple organizations, this research focusses on interorganizational projects (Jones & Lichtenstein, 2008). Inter-organizational projects involve two or more legally independent organizational actors working jointly to create a tangible output during a limited period of time (Jones & Lichtenstein, 2008).

Interorganizational projects are present in numerous industries and sectors. To mention few examples, Olympic games events (Grabher & Thiel, 2012), large infrastructure projects (Yang et al., 2022) or megaprojects (E. Daniel & Daniel, 2019). Each type of project has its own unique characteristics, challenges and success factors (Jones & Lichtenstein, 2008). In this sense, this research specifically focuses on interorganizational innovation projects (Eriksson et al., 2016) which are also commonly known as collaborative projects (Fernandes et al., 2021).

The underlying motivation of a collaborative project is to leverage the innovation efforts of multiple organizations working together to collectively deliver complex and novel outputs (vom Brocke & Lippe, 2015). Organizations are increasingly embracing open boundaries to enhance their innovation processes, with collaborative projects serving as a key vehicle for the effective implementation of innovative efforts (Klessova et al., 2022; Nisula et al., 2022). In spite of the increasing interest of companies to develop collaborative projects, most of them, fail to meet performance and success objectives (Fernandes et al., 2021; Michelfelder & Kratzer, 2013). This sentence clearly defines the research problem we address in this monography. The following section describes the main challenges that project participants face in the context of collaborative projects and their implication on project results and their success measures.

2.2 The nature of collaborative projects.

Within the broad diversity of interorganizational project typologies, the concept of collaborative project has acquired higher relevance in the last 15 years (Klessova et al., 2023; vom Brocke & Lippe, 2015). The growing interest in this area is a direct response to recognizing the strategic significance of projects as a means to deliver innovation through collaboration (Gama et al., 2017). It is widely acknowledged that interorganizational innovation projects offer superior innovation results compared to intra-organizational innovation projects (West, Salter, Vanhaverbeke, & Chesbrough, 2014).

In addition to the project characteristics of time, task, transition, team (Lundin & Söderholm, 1995), context (Bakker, 2010), and the legal independence of team members (Jones & Lichtenstein, 2008), collaborative projects present unique challenges that make their management more complex.

First, the motivation to join the project. By opening their boundaries to external organizations, companies can access to valuable and scares external resources and knowledge, share risk and cost that at the end, boost their innovation processes (Gama et al., 2017; Gassmann & Enkel, 2004; Patel, Parida, Jayaram, & Oghazi, 2018). It has been proven that companies accelerate innovation by leveraging external (and scarce) sources of knowledge and capabilities, rather than relying solely on their existing knowledge and resources (West et al., 2014). Additionally, since innovation is inherently associated with risk and uncertainty, accessing complementary resources enables cost reduction and risk mitigation.

In addition to the reasons that motivate companies to participate in collaborative projects, it is crucial to highlight the significant challenges associated with their management in order to describe its complex reality:

- Diversity of partners:

Representatives from academic institutions, private companies, and public organizations converge, forming a diverse collective with a shared aim of accomplishing a common objective (Chiaroni, Chiesa, & Frattini, 2010; vom Brocke & Lippe, 2015). On the one hand, bringing together actors from different knowledge fields, industries, and cultures provides a rich environment for the development of innovative products, services, and technologies (Nisula et al., 2022; vom Brocke & Lippe, 2015). On the other hand, this collaborative environment presents significant managerial challenges for the partners involved in the projects (Derakhshan et al., 2020; Eriksson et al., 2016). This is basically because a diverse range of knowledge backgrounds, working methodologies, and interests coexist, all aiming to develop novel, complex, and innovative outputs (Klessova et al., 2020; Malherbe, 2022). Each partner has their own way to understand the reality, based on its own background and working methodologies (Daft & Lengel, 1986). Information will be subject to different interpretations according to the partner´s background and sectors. In addition, working methodologies are contingent to the sector where each partner is working on. For example, Du et al. (2014) argue that team members from industrial backgrounds operate in environments characterized by regular monitoring and strict control, while scientists typically work in settings with more autonomy, academic freedom, and flexibility for improvisation. Science-based partners may experience discomfort when they are required to adhere to strict monitoring or regular controls and vice versa (Du et al., 2014).

In collaborative projects, diversity includes not only backgrounds but also, individual interests. Although all partners may have a shared overarching goal, each one possesses their distinct and sometimes conflicting interests within the project (Enger & Gulbrandsen, 2020; Malherbe, 2022). For instance, while some partners may view a collaborative project as an opportunity to drive innovation that they could not achieve independently, others may perceive the same project as a mean to secure funding for their operations. Then, while scientists are more concerned with advancing scientific knowledge as the main goal of the project, market-based partners are primarily interested in the potential business benefits of the project outcomes (Du et al., 2014). Therefore, aligning the broad diversity of individual interests of partners into a common goal represents one of the main challenges for project managers.

The diversity of backgrounds and interests adds complexity to the decision-making process, information perception and project plan execution (Burström & Wilson, 2018; Malherbe, 2022; von Raesfeld, Geurts, & Jansen, 2012). Stakeholder management is important in all types of projects, but it becomes even more relevant in the context of collaboration, where a broad diversity of backgrounds and interests coexist (Oliveira & Fernandes, 2022).

- Collaborative relationship among partners.

As Calamel et al. (2011) work clearly stated "*in collaborative projects, they're people coming together to solve a problem. They're different from the relationship between a principal contractor and a number of subcontractors*". The autonomy and equality of consortium members distinguish this type of partnership from the traditional *customer-supplier* model, leading to unique conditions in terms of project governance and the exercise of authority (Calamel et al., 2011; vom Brocke & Lippe, 2015). That is because decision-making process, authority and responsibilities are shared collectively between partners (Klessova et al., 2020). This represents an issue because, in the event of conflicts or tensions, partners cannot rely on the formal authority of the sponsor to resolve such matters. Instead, they must align themselves collectively to address these challenges. This highlights the importance of project managers and their leadership approach, as relying on authority to govern relationships is neither recommended nor always allowed in the context of collaboration (Morandi, 2013).

- The opposing nature of collaborative projects.

Collaborative projects, like most of the innovation projects, face the challenge of balancing dual and conflicting innovation processes, namely exploration and exploitation, within a single project (Sætre & Brun, 2012). They necessitate a high level of creativity and novelty, while simultaneously achieving the triple constraint objectives in a cost-efficient manner (Brun, 2016). How to achieve a proper combination of exploration (associated with novelty) and exploitation activities (associated with

efficiency) during the project lifecycle is an outstanding challenge for project managers (Solís-molina et al., 2020; Tiwana, 2008).

- Unclear, ambitious, ambiguous and moving project goals.

In most cases, the project's goal is initially unclear and often undergoes changes throughout the project lifecycle (Gama et al., 2017; Sakka, Barki, & Côté, 2016). In many cases, when a collaborative project is funded by an external organization, such as a public agency, the project results are expected to represent a significant advancement in the state of the art in science, technology, or the market. This often leads the partners to propose ambitious objectives, that are usually subject to changes during the lifecycle (Fey & Kock, 2022). Additionally, defining ambiguous goals and objectives is not solely a result of the high novelty of the desired output; it is often a deliberate project strategy (Stetler & Magnusson, 2015). Ambiguity in goals and objectives can foster innovation by allowing for a greater range of alternative options and a larger space for solutions. This ambiguity has the potential to generate ideas that explore entirely new directions (Stetler & Magnusson, 2015). However, several managerial problems emerge from that, such as difficulties to align partners, the allocation of resources, or the motivation of the team without a clear vision of the desirable future (Brun, 2016). According to Davenport et *al*. (1999), one of the primary reasons cited by managers for the failure of collaborative projects is the presence of unclear and unrealistic goals.

- Tacit knowledge integration.

Collaborative projects consist of an intensive knowledge integration process (Faccin et al., 2019). This knowledge is mainly tacit and intangible, and it is drawn from diverse knowledge sources such as universities and industrial organizations (Du et al., 2014). Combining the knowledge (mainly tacit) of individuals from diverse sources, each one with their own unique skills, experiences, and organizational cultures and structures, poses significant complexities and challenges (Faccin et al., 2019). How to identify and effectively integrate these external and tacit knowledge in order to produce tangible and valuable outputs is a critical success factor for all the innovation efforts (Dietrich, Eskerod, Dalcher, & Sabdhawalia, 2011; Sakka et al., 2016). The challenge lies in bridging the knowledge gaps between partners to establish a common understanding that facilitates the flow of knowledge from one party to another, ultimately materializing as a project output (Tiwana, 2008).

- Lack predictability capacity.

Lastly, the degree of novelty in the project's outputs presents a challenge for managers as it hinders their ability to predict the final product and, consequently, develop a plan to reach it (P. Daniel & Daniel, 2018; Williams, 2005). Project Management tools and techniques are primarily designed for

predictable contexts. Therefore, it is suggested that these methods may not be effective in dealing with the innovativeness, complexity, and uncertainty inherent in collaborative projects (Kapsali, 2011). In this regard, the final output emerges through the interaction between partners rather than being fully predetermined in advance (Geraldi, Maylor, Williams, & Williams, 2011). The lack of predictability capacity of managers makes difficult resource´s allocation, risks mitigation, coordination and control, change management among others managerial aspects of the project (Cooke-davies et al., 2009).

The growing complexity of projects poses an ever-greater challenge to their management. However, there are specific issues and characteristics of collaborative projects that make their management more complex, complicated and uncertain than other project typologies. The aforementioned issues constitute relevant challenges and serve as the primary causes of project failures. Table 1 provides a summary of the collaborative project´s characteristics.

Project characteristics	References	Managerial implications
Partner´s diversity	(Calamel et al., 2011; Chiesa & Frattini, 2007; Malherbe, 2022; Nisula et al., 2022; Raesfeld, Geurts, Jansen, Boshuizen, & Luttge, 2012; vom Brocke & Lippe, 2015)	The diversity of backgrounds and interests adds complexity to the decision-making process, information perception, stakeholder´s alignment and project plan execution.
Collaborative relationships	(Calamel et al., 2011; Klessova et al., 2020; Malherbe, 2022)	This adds complexity to decision-making process, resource´s allocation and stakeholder´s alignment.
Opposing nature of collaborative projects	(Brun, 2016; Brun, Saetre, & Gjelsvik, 2009; Solís-molina et al., 2020)	How to achieve a proper combination of exploration (associated with novelty) and exploitation activities (associated with efficiency) during the project lifecycle.
Tacit, unclear, ambiguous and moving project goals.	(Gama et al., 2017; Sakka et al., 2016; Stetler & Magnusson, 2015)	How to align partners, resource´s allocation, schedule activities or maintaining the motivation of the team without a clear vision of the desirable future.
Tacit knowledge	(Du et al., 2014; Faccin & Balestrin, 2018; Tiwana, 2008)	How to identify and effectively integrate external and tacit knowledge in order to produce tangible and valuable outputs.
Lack of predictability capacity	(Cooke-davies et al., 2009; P. Daniel & Daniel, 2018; Geraldi et al., 2011; Maylor, Geraldi, Budzier, Turner, & Johnson, 2023)	Resource´s allocation, risks mitigation, coordination and control, change management and the implementation of well-established PM tools and techniques

Table 1. Summary of collaborative project´s characteristics

2.3 The meaning of success in project management.

The concepts of project "performance" or “success” have been extensively researched in the field of project management, making them one of the most, if not the most, explored topics (Padalkar & Gopinath, 2016; Söderlund, 2011). Over the past 50 years, various research streams have emerged with the aim of offering a more comprehensive perspective on understanding the meaning of performance and success in projects and assisting project managers in the successful development of their projects (Ika & Pinto, 2022). However, the discussion is far from being closed; in fact, there is a growing interest within the scientific community to further explore these concepts in relation to contemporary project typologies and contingencies (Maylor et al., 2023). In this regard, two special issues (project performance and project success) have been opened in the most relevant journal in project management studies (the International Journal of Project Management), during 2022 and 2023, respectively.

The increasing complexity of projects has led to the emergence of multiple perspectives on what constitutes performance and success in projects (Padalkar & Gopinath, 2016). The terms "success" and "performance" have been interchangeably employed to evaluate project outcomes. Rather than delving into a terminology debate, this research opts for "project success" as the preferred mean of assessing project results. The choice between "success" or "performance" does not alter the essence of the research. Nevertheless, for the sake of syntactical cohesion, we will consistently refer to "project success" as the method for measuring project outputs and outcomes.

During the first decades of the project management discipline, deterministic approaches were predominant to measure project success as the successful accomplishment of the iron triangle objectives: quality (scope), time and cost (Atkinson, 1999). This perspective has been predominantly embraced by international Project Management associations, such as PMI (Project Management Institute), which have developed extensive bodies of knowledge whose primary focus was on project management research at operational levels (P. Daniel & Daniel, 2018). Normative and instrumental tools, processes, and methodologies were designed to enhance project success, with a primary focus on achieving the objectives of the iron triangle (Svejvig & Andersen, 2014). In this perspective, the unit of analysis is the project *output*: the result of the project implementation or execution phase (P. Daniel & Daniel, 2018). The underlying assumption was that the project possesses fixed and deterministic attributes, and project managers should develop it in a cost-efficient manner (Kapsali, 2011). The iron triangle offers an effective manner to measure the efficiency implementation of the project plan. This approach is often referred as the efficiency paradigm (P. Daniel & Daniel, 2018). However, customer satisfaction is not solely contingent on the timely and cost-effective development of projects; it also

hinges on the benefits obtained and the value perceived by stakeholders from the project outcomes (Laursen & Svejvig, 2016; Pargar, Kujala, Aaltonen, & Ruutu, 2019).

During the 1990s and particularly at the beginning of the new century, a new research stream emerged, building upon the work of Morris (1994) about rethinking project management. According to Morris's perspective, there should be a shift in emphasis from solely focusing on product creation to adopting a holistic approach that encompasses both value creation and the realization of benefits (Cooke-davies et al., 2009). Value is a complex, interdependent, and multi-dimensional concept that is not absolute but rather relative, and it may be perceived differently by different parties in varying situations (Laursen & Svejvig, 2016). In short, value can be generally defined, as the result of a trade-off between benefits and costs in the management of projects and their outcomes (Matinheikki, Artto, Peltokorpi, & Rajala, 2016). It is a multidimensional and dynamic concept as it is created in a constellation of multiple organizations and it is captured (value realization) by the stakeholders in an ongoing and long term (emergent) process, as compared to the traditional output's measures (H. Smyth, Lecoeuvre, & Vaesken, 2017; Svejvig & Andersen, 2014; Williams, 2005). Non-deterministic approaches were applied in the last years as a vehicle to capture holistically success as a dynamic and highly subjective concept, viewing it beyond the iron triangle (Maylor et al., 2023).

As a summary, project success under the perspective of "efficiency" is a short-term orientation that considers how effective the project accomplishes the initial objectives regarding cost, time and scope/ quality (Cooke-davies et al., 2009; Padalkar & Gopinath, 2016). It is focused on the contribution of the project to the final output during the project implementation phase (Söderlund, 2011). The second one is a long-term orientation that deals with the project's contribution to the organization's outcomes (P. Daniel & Daniel, 2018). The emphasis is on strategic value (Cooke-davies et al., 2009; Eweje, Turner, & Müller, 2012; Laursen & Svejvig, 2016) and long-term benefits for the stakeholders and their environment (Laursen & Svejvig, 2016). The debate regarding which paradigm is more useful for assessing project success for project managers remains ongoing, as it is contingent upon the specific project context and its characteristics.

As expected, there are articles that have made efforts to integrate both perspectives into comprehensive models, such as Shenhar et al. (2001), Chiesa and Frattini (2007), and Ika and Pinto (2022). In all of these cases, the research output is a model that includes measures to assess success in terms of efficiency and value. For example, the most recent model proposed by Ika and Pinto (2022) combines project success measures such as plan success, business success, objective evaluations, subjective stakeholders' perceptions of success, and sustainability success. The first measure focuses

on the effective development of project outputs, while the remaining measures address the medium- and long-term implications of the project outcomes (Ika & Pinto, 2022).

Despite the existence of models that attempt to integrate both perspectives, the decisions made by project managers during project execution are highly influenced by how project success is measured. There are instances within the project where the two perspectives are irreconcilable, leading to potential conflicts or dilemmas among partners. In this sense, there are permanent trade-offs between the efficiency and value paradigms, and project managers need to consider what is most suitable for the specific requirements of the project. Figure 1 represents a summary of perspectives regarding project success.

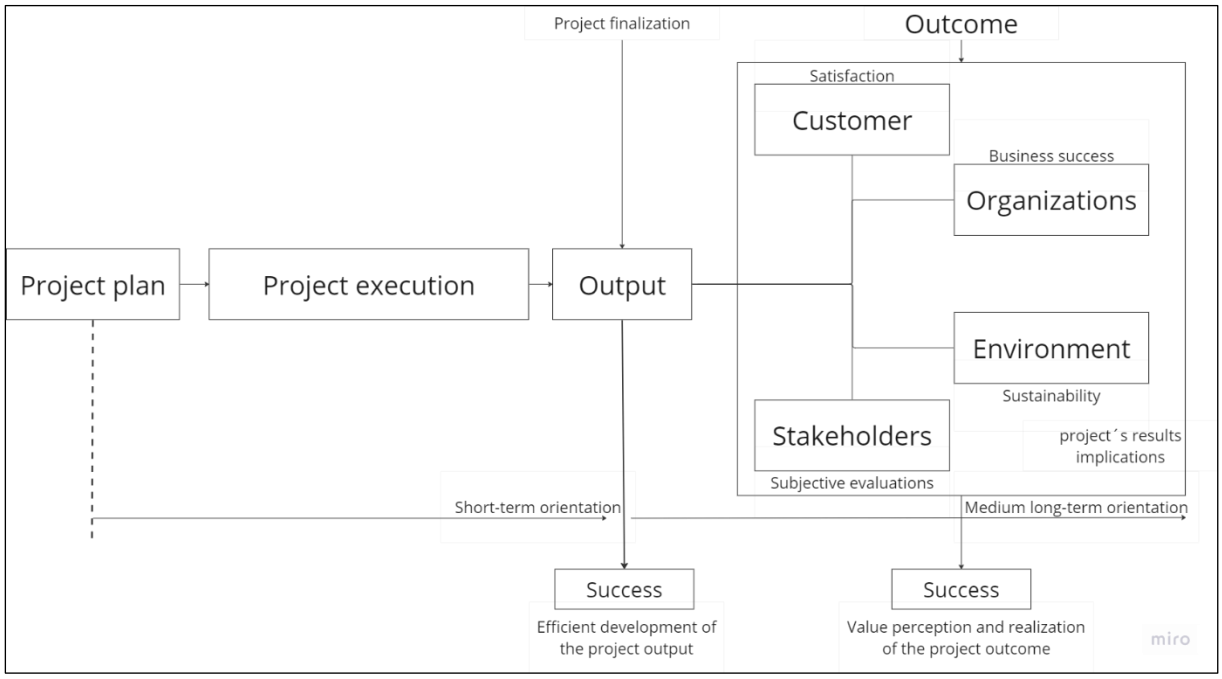


Figure 1: Summary of perspectives regarding project success

The measurement of project success is highly contingent upon the specific nature and characteristics of the project itself. In less uncertain environments where the project requirements can be somewhat accurately estimated, efficiency approaches contribute to improving resource allocation, scheduling, and cost reduction. This is evident in projects such as construction projects, system implementation, or event management (Söderlund, 2004). However, in more unpredictable, uncertain, and ambiguous environments, evaluating a project solely based on the efficient development of an output fails to capture the essence of such projects. The true essence lies in the added value that the project's results bring to the stakeholders involved (Laursen & Svejvig, 2016). In this sense, the next section analyses the project success in the context of collaborative projects.

2.4 Success in collaborative projects.

Collaborative projects are considered as the vehicle to deliver the innovation efforts of the involved organizations (Calamel et al., 2011). They are driven by a need to develop complex and unique outputs that cannot be developed by individual organizations alone (Gama et al., 2017). Often, the project goal is unclear, ambiguous and it changes along the project lifecycle. Assessing the success of collaborative projects solely in terms of inputs versus outputs, with a focus on their efficient development, poses certain challenges because developing outputs does not necessarily imply delivering value (Laursen & Svejvig, 2016). In this sense, innovation is inherently associated with value rather than efficiency (Stetler & Magnusson, 2015).

The heterogeneity of partners with diverse interests and backgrounds poses additional challenges in terms of project success. Given that project goals are often ambitious and ambiguous, each partner may interpret them differently based on their own interests and backgrounds. As the project progresses, the goals are constantly refined and negotiated among partners, and the project output emerges from the interactions between partners rather than being strictly based on predetermined plan-based actions (E. Daniel & Daniel, 2019; Majchrzak et al., 2015). Assessing success based solely on output measures, especially when the output is a result of the partner´s negotiations, may be incomplete.

Lastly, according to Urabe (1988), innovation is defined as the generation of a new idea and its subsequent implementation in a new product, service, or process. The inherent uniqueness of the idea implies that customers and stakeholders will gradually recognize and experience its benefits in an ongoing and dynamic process of value realization (Pargar et al., 2019). The process of realizing project benefits extends beyond the completion of the project itself, encompassing ongoing value realization processes. Merely assessing project benefits immediately after project closure would be incomplete, as it fails to capture the continuous and evolving nature of value realization (Pargar et al., 2019).

In this regard, the uncertain nature of collaborative projects, coupled with their innovation objectives, ambiguous and ambitious goals, and the limited predictability capacity of managers, renders the process of assessing success based solely on the efficient paradigm, at least incomplete. Measuring project success as a dynamic and subjective process of value realization and capture between stakeholders during and after the project, seems to be more appropriate in the context of collaborative innovations, complementing the efficiency´s perspective (Chiesa & Frattini, 2007; Laursen & Svejvig, 2016; vom Brocke & Lippe, 2015). Rather than favouring one perspective over the other, this research underscores the importance of both paradigms in measuring project success. The

objective is to analyse the trade-off between equivocality and governance, as well as their implications in project results, by considering these two paradigms as a means to evaluate their success.

2.5 Equivocality in collaborative projects.

Managing equivocality is a central organizational challenge, particularly in the context of innovation (Frishammar et al., 2011). Equivocality refers to the presence of multiple and conflicting interpretations of a goal, situation, or task (Daft & Lengel, 1986). In collaborative projects, managing equivocality becomes an increasingly challenge (Eriksson et al., 2016). Collaborating firms bring together individuals with diverse experiences, skills, resources, capabilities, and frames of reference that might lead to conflicting interpretations of tasks, routines, goals, and information (Kleinsmann, Buijs, & Valkenburg, 2010). Consequently, misunderstandings arise as partners have divergent interests, terminologies, orientations, and cultures (Gama et al., 2017). The presence of unclear and evolving project objectives, coupled with high levels of uncertainty, exacerbates the diversity of interpretations and increases equivocality (Gama et al., 2017; Sakka et al., 2016).

There are identifiable indicators that can help in recognizing when a team is facing equivocality issues. For instance, when team members rely on symbols or metaphors rather than providing accurate definitions or logical arguments to express their viewpoints (Stevens, 2014). Another sign is when individuals explain situations with a lack of clarity, high complexity, or resort to paradoxes (Frishammar et al., 2011). In addition, equivocality issues become apparent when there is a noticeable disparity in commitment levels among collaborative partners, highlighting the existence of divergent interests within the project. These differing interests often overshadow the pursuit of common goals (Malherbe, 2022). Equivocality issues may also arise when there is a substantial knowledge gap between partners, leading to divergent interpretations of similar information based on their respective backgrounds. Last, equivocality emerges also as a matter of working methodologies. Science-based partners are accustomed to practices that foster greater freedom and creativity, while market-based partners are more familiar with strict monitoring and task control approaches (Du et al., 2014). Defining and developing working methodologies are highly subject to equivocality.

During the last years, equivocality has been conceptualized as a double-edged sword in collaborative projects (Eriksson et al., 2016; Marcandella & Guèye, 2018). On the one hand, equivocality fosters the emergence of divergent and competing interpretations, which can enhance the recombination of knowledge and facilitate the exploration of different possibilities (Brun, 2016; Fleming, 2001). This also encourages interorganizational teams to engage in discussions that challenge existing understandings of information and tasks (Eriksson et al., 2016). This process of managing equivocality stimulates the exchange of salient beliefs and interpretations among team members, contributing to

a deeper and higher-level learning process (Marcandella & Guèye, 2018). In this sense, equivocality has positive implications in the project results, by fostering knowledge exploration processes (as a driver), contributing to the process of value creation, relevant in innovation efforts.

On the other hand, high levels of equivocality can have negative impacts on project results (Frishammar et al., 2011; Stevens, 2014). The presence of equivocality can impede the establishment of a common understanding among project participants regarding what needs to be developed, the project goals, and the subsequent procedures (Eriksson et al., 2016). This lack of alignment and clarity, originated by conflicting interpretations can persist throughout the project lifecycle, potentially leading to undesirable outcomes (Rönnberg Sjödin, Frishammar, & Eriksson, 2016). If not effectively addressed and mitigated, significant levels of equivocality can ultimately result in project failure (Frishammar et al., 2011). In this sense, equivocality increases tensions between partners, restraining process of knowledge exploration and integration, affecting negatively the development of project results.

2.6 Governance in collaborative projects.

Governance in projects comprises the use of systems, agreements, authority structures, leadership, actions, decisions, and processes to allocate resources, as well as coordinate and control activities, with the aim of defining and achieving project goals (Pinto, 2014). In the context of collaboration, governance is not only focused on achieving project goals but also on enhancing collaborative capacity among partners (Vangen, Hayes, & Cornforth, 2015). Governance has been conceptualized in several ways in the literature. In this research, we follow the approach of Gulati et *al.* (2008) and Poppo & Zenger (2002), that considered governance as the complementarity or substitution effects of relational and contractual mechanism.

Contractual governance pertains to the establishment of formal, explicit, and legally enforceable agreements (Gulati & Nickerson, 2008; Poppo & Zenger, 2002). These agreements define the roles, rights, and responsibilities of partners, while also implementing safeguards to mitigate potential opportunistic behaviours (Chakkol, Selviaridis, & Finne, 2018). These also establish the deliverables to be provided, monitoring procedures and milestones (Cao & Lumineau, 2015). For instance, the collaborative agreement, mutually agreed upon by all parties involved, explicitly outlines the desired project outputs and their associated objectives in terms of time, cost, and quality. Subsequently, a plan is implemented, where is included the allocation of resources among partners, clear delineation of responsibilities, identification of activities, and establishment of milestones.

Relational governance, or usually referred as “social control” or “relational mechanism”, refers to which extend interorganizational relationships are governed by social relations or shared norms

(Gulati & Nickerson, 2008; Poppo & Zenger, 2002). Relational governance has been frequently associated with two concepts, relational norms and trust (Arranz & de Arroyabe, 2012; Cao & Lumineau, 2015). Relational norms pertain to the values and social rules that project coalition members informally share among themselves (Benítez-Ávila et al., 2018). Trust is characterized by the confidence and belief in the integrity, credibility, and benevolence of a partner within a relationship that involves uncertainty, risks and opportunism behaviours (Cao & Lumineau, 2015). Relational norms and trust are not assumed as given at the outset of collaboration; rather, they are nurtured and developed throughout the project lifecycle as a socially constructive process (Davenport, Davies, & Grimes, 1998). Relational norms are essential to build partner trust, which in turn directs the allocation of resources, ensuring valuable contributions from each partner (Benítez-Ávila et al., 2018).

Relational and contractual governance have acquired considerable attention in various organizational studies, including strategy, alliances, networks, and particularly in our case, project management (Gulati et al., 2012; Pinto, 2014; Poppo & Zenger, 2002; Söderlund, 2011). In many cases, the discussion revolves around the role of governance modes and how they interact with each other, exploring whether they act as substitutes or complements (Benítez-Ávila et al., 2018; Cao & Lumineau, 2015; Poppo & Zenger, 2002; Solís-molina et al., 2020). The underlying assumption is when contractual and relational governance are complements (or substitutes), they have complementary (or substitute) impacts on the project results (Cao & Lumineau, 2015). This suggests that when one form of governance is implemented, it increases (or diminishes) the extent of the benefits of the other form.

The research stream that supports substitution claims that contracts are redundant when the relationships can be managed based on trust or vice versa (Wang, Yeung, & Zhang, 2011). It is also viewed that an increased dependency on formal agreements is a signal of lack of trust or a preventive action to reduce opportunism (Poppo & Zenger, 2002). In situations where, formal governance is deemed sufficient for the involved parties, relational governance can be perceived as a costly expense. Developing relational governance requires significant investments of time and resources, which can potentially have a detrimental impact on efficiency objectives (Poppo & Zenger, 2002).

On the other hand, the perspective advocating for complementarity argues that either relational or formal governance "enables" the necessary conditions to support the other type (Huber, Fischer, Dibbern, & Hirschheim, 2013). In addition to enabling mechanism, a "compensating" mechanism also plays a role in addressing the limitations of the other governance type (Cao & Lumineau, 2015). For instance, having clear definitions of roles and responsibilities policies enhances trust among partners, serving as an enabling factor (Davenport et al., 1998). Then, trust among partners can facilitate seamless adaptation of contracts to new and unforeseen situations. This can enable the establishment

of updated guidelines and a legal framework for the evolving relationships among partners, compensating for the limitations of the initial ones.

At the project level, there are several studies that investigate the effects of governance approaches into the project success (Arranz & de Arroyabe, 2012; Chakkol et al., 2018; Pinto, 2014). However, in the field of collaborative relationships, the interplay between governance approaches and their impact on the project results remains surprisingly understudied and opposing perspectives coexist (Benítez-Ávila et al., 2018). Solis-Molina *et* al. (2020) found that in co-exploitation projects where the uncertainty of the context and novelty of the output is lower, better results are associated with formal governance rather than relational ones. It is similar with Olander et *al.* (2010), that found that during the exploitation phase of R&D collaborative projects, contractual governance demonstrates superior results compared to relational governance, and the absence of contractual agreements affects negatively the project results. In exploration phases, due to the higher uncertainty and novelty, relational governance enables better adaptation to unpredictable issues, producing better results (Olander, Hurmelinna-Laukkanen, Blomqvist, & Ritala, 2010). During exploration phases, the combination of relational norms and contractual agreements can sometimes introduce additional ambiguity, potentially giving rise to partner confusion, conflicts, or mismatched expectations, affecting negatively the project results (Solís-molina et al., 2020). In these cases, substitution effects (either or) have been associated with better results in project success measures.

However, Benitez-Avila *et* al. (2017) found positive effects of the complementarity role of governance approaches, acting as enable/compensator in public-private partnerships. They suggest that a contractual agreement is a necessary condition to rule the partners behaviours, but it is not enough to assure partner implications, in which relational approaches translate contractual provisions into real partner´s contributions. This relationship is made of mutual causality and when it is found, it is associated with better project results (Benítez-Ávila et al., 2018; Cao & Lumineau, 2015).

The majority of researchers agree on the positive effects of both relational and formal governance in relation to project success objectives, as these governance approaches are primarily aimed at achieving such objectives. However, contrasting research perspectives coexist, supporting the notion of complementarity or substitution effects between both approaches and their impact on the project outcomes. The debate is still open. In addition, it is also not clear their implications on project success in terms of efficient development of outputs or valuable delivery of outcomes. To what extent either relational or formal approaches affect either output or outcomes success measures is still unknown. This research aims to elucidate this research gap, by explaining the interplay between governance approaches, equivocality and output/outcome project success perspectives in collaborative projects

2.7 Interplay between equivocality and governance.

Despite the independent significance attributed to both constructs and the extensive body of knowledge surrounding them, they are intricately interdependent. The majority of research has focused on examining either equivocality or governance and their respective impacts on project results. However, our claim is that each of these constructs not only influences project results but is also influenced by the behaviours of the other.

On the one hand, contractual agreements play a crucial role in clarifying roles and responsibilities, thereby reducing the range of potential interpretations, minimizing equivocality (Yang et al., 2022). Relational approaches enable knowledge exchange and a deeper communication required to align different perspectives, providing a common understanding and thus, reducing equivocality (Derakhshan et al., 2020; Sakka et al., 2016). Relational exchanges, such as face-to-face meetings, play a significant role in fostering trust by facilitating a deeper understanding and creating an environment conducive to collaboration and consensus. In potential conflictive situations, the presence of trust between partners can contribute to an increased willingness to reach a mutual agreement, prioritizing shared goals over individual ones and reducing equivocality. Lastly, trust also empowers partners to demonstrate flexibility, creativity, and open-mindedness, all of which are vital for generating innovative ideas at the ambiguous early stages of a project. This enhances knowledge exploration processes and, consequently, amplifies the positive impacts of equivocality on the project results (Brun, 2016). In this sense, the implications of equivocality on project results are positively moderated by the governance approaches employed to manage it. Positive implications are encouraged by more relational approaches and negative implications are mitigated either by relational or contractual governance.

On the other hand, relying on what has been contractually agreed might limit the emergence of novel or innovative solutions, reducing flexibility and creativity required to solve unknown issues (Gonzalez, 2022; Parida, Patel, Frishammar, & Wincent, 2017; Sicotte & Langley, 2000). Specific contractual agreements limit the emergence of different perspectives, reducing the positive implications of equivocality on innovativeness. Then, in uncertain situations, contractual agreements might be also a source of misunderstandings, as the partners might conceive the unknown situation and its contractual implications in a very different way (Morandi, 2013). In this sense, contractual agreements serve not only as a way to mitigate equivocality but also as a source that amplifies the diversity of conflicting interpretations, increasing tensions between partners. Additionally, increasing communication through relational approaches might also be detrimental, as the tensions between partners might be even exacerbated, following a negative loop made of arguments and counterarguments, increasing time and resources invested in communication but reducing the

possibility of reaching common agreements (Knudsen & Srikanth, 2014). Contractual and relational approaches might also exacerbate equivocality issues and their negative implications.

In summary, equivocality and governance approaches are closely interconnected, with each one influencing and being influenced by the behaviours of the other. Rather than being static or linear, this relationship is mutual and dynamic and yields varying outcomes based on the evolution of the interaction. This research approaches the problem of equivocality and governance in collaborative projects in a dynamic and comprehensive manner, as each one affects and is affected by the behaviour of the other (Figure 1). Additionally, the implication of each one on the project results is moderated by the effects of the other. Approaching equivocality or governance and their implications on project results in an individual / static approach seems to be incomplete to explain project results and success in collaborative projects. Figure 2 represents the initial framework configuration aimed to visualize the mutual and dynamic interdependencies between these three constructs.

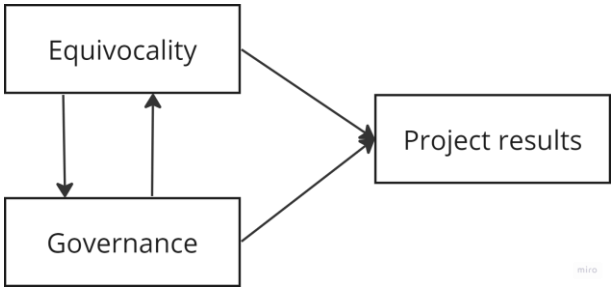


Figure 2: Mutual interdependencies between equivocality, governance and the implications in project results

2.8 Initial Research GAP and initial research framework proposal.

Dealing with equivocality and its implications on the project results is one of the most challenging issues, if not the most challenging one, to tackle throughout collaborative projects (Frishammar et al., 2011). A wide range of partner´s interests and backgrounds coexist within the project, leading to a diverse array of interpretations (which can sometimes be conflicting) (Stevens, 2014). The presence of such diversity can have both positive and negative implications on the project results, making it a double-edged sword (Eriksson et al., 2016). Governance approaches are also a central issue in collaborative projects, as they are designed to increase the likelihood of project success, either acting as substitutes or complements (Cao & Lumineau, 2015). Additionally, changes in governance approaches might increase or reduce equivocality levels, either exacerbating or mitigating their positive or negative implications (Eriksson et al., 2016).

In this sense, the project results (considered as outputs and outcomes) are affected by the dynamic evolution of the relationship between governance and equivocality, rather than the individual

implications arising from each of them in isolation (Brun, 2016; Majchrzak et al., 2015). However, these mutual implications remain underexplored, leading to a refined research question:

How does the interplay between equivocality and governance affect the project results, under the success perspectives of efficiency and value?

Different approaches have been applied to capture the dynamic evolution of collaboration, for instance, by Majchrzak et al. (2015); Browing et al. (1995) or Ness (2009) to mention some of them. Ness (2009) found that differences in project goals and partner´s interests (equivocality) lead to conflicts among partners. These tensions have been exacerbated by the increasing use of more contractual governance, starting a negative loop of increasing tensions that finally led a project to failure. On the other hand, Browning et al., (1995) found that similar tensions among partners were also the drivers that lead the project to change. In this case, more relational approaches have been adopted among partners, leading a better process of knowledge exchange and further improvements in partner´s cooperation, associated with positive results.

Both examples represent the dynamic nature of the evolution between equivocality and governance in collaborative projects. However, there are no evidence that capture to what extend these evolutive process affects the project results in terms of outputs or outcomes. That is the initial research gap that this research aims to fill. The graph Figure 3 represents a draft of the initial research framework proposal.

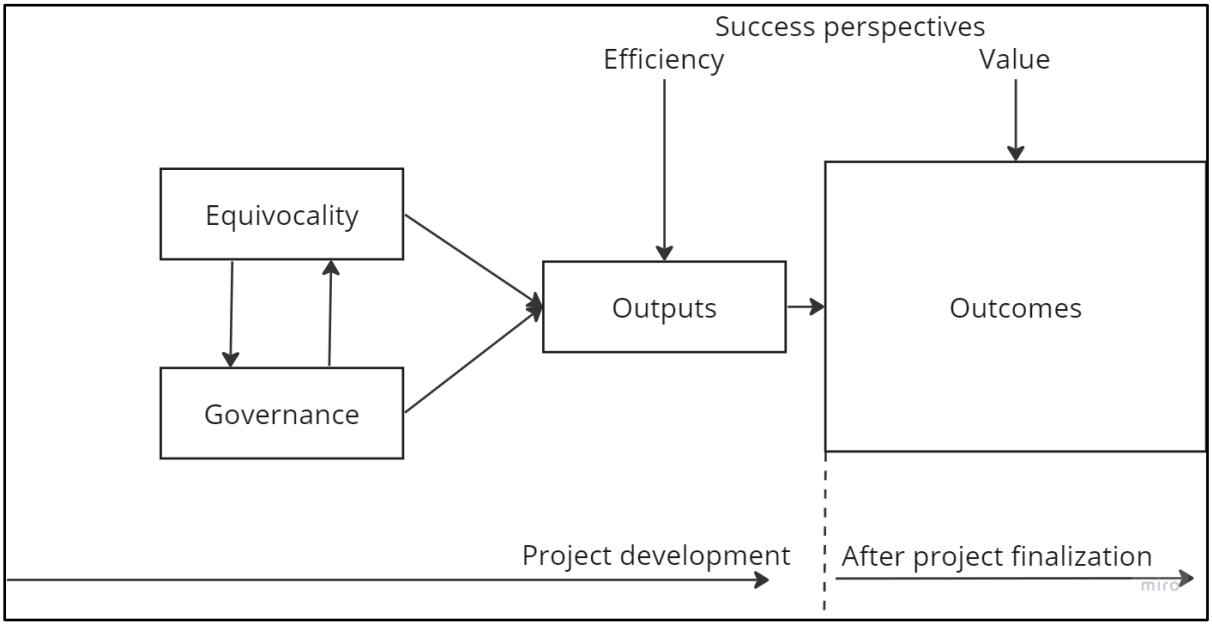


Figure 3: Preliminary research framework proposal aimed to capture the evolving relationship between equivocality, governance and project results (under perspectives of success and efficiency)

In the context of collaborative projects, understanding the implications of the trade-off between equivocality and governance approaches into the project results is relevant for the following reasons. Firstly, since the primary objective of collaborative projects is to foster innovation (Klessova et al., 2022; Marcandella & Guèye, 2018), comprehending the implications of both equivocality and governance solely on output or outcome success measures would be incomplete, to say the least. In this sense, understanding the implications of the evolution of this relationship and its implications into the project results, evaluated based and their different success perspectives, is still an understudied topic that deserves further attention.

Second, most of the knowledge in the project management field, is framed under the umbrella of the operational project perspective (efficient development of outputs) rather than strategic perspective (value delivered by outcomes) (P. Daniel & Daniel, 2018). However, many innovative projects fail to meet stakeholder expectations (Fernandes, O' Sullivan, Pinto, Araújo, & Machado, 2020; Michelfelder & Kratzer, 2013), and one of the reasons behind this can be attributed to the heavy reliance on plan-oriented tools and techniques that prioritize reducing equivocality, often at the expense of the emergence of novel outcomes. This has an impact on stakeholder´s value assessments. Further research is needed to elucidate the potential positive implications of equivocality on the project results and the ways in which governance can contribute to this (Eriksson et al., 2016; Marcandella & Guèye, 2018).

3. Methodology.

The objective of this research is to enhance the existing understanding about project success in collaborative projects and the impact of equivocality and governance on their output/outcome measures. The research framework presented in the literature aims to establish hypothetical relationships among the three constructs. However, while this framework provides a comprehensive theoretical overview of the phenomenon, it would greatly benefit from a more empirical grounded detailed and focused analysis.

The part I of this research work is exploratory in nature, aiming to improve the understanding of an underexplored phenomenon by complementing the existing literature's framework with empirical insights derived from project managers' experiences. The main objective is to validate and refine the framework described in section 2 with empirical data obtained by open interviews with project managers that have participated in collaborative projects. The refined framework presented in the discussion of the Part I serves as a starting point for Part 2, where the scientific contribution is further developed.

For exploratory studies, open-ended interviews are suitable for gaining deeper understanding, allowing the researcher to go deeper into emergent insights rather than focusing on specific themes (Corbin & Strauss, 1990). The data analysis in this section adopts the methodology outlined by Corley and Gioia (2004), which is based on the grounded theory approach. This approach allows for the empirical comparison of models based on empirical data.

3.1 Data collection strategy.

To explore an under-researched topic, a series of exploratory open interviews were conducted with senior project coordinators involved in a wide range of collaborative projects. A total of six interviews were carried out to gather valuable insights from their extensive experience. The interviews lasted approximately 45 minutes each. They have taken place from July 2021 to July 2022. While an interview protocol was followed, the discussions naturally turned towards different topics as they unfolded. Open-ended interviews allow the researcher flexibility to adapt the questions to specific topics, thus maximizing the value derived from the data (Corley & Gioia, 2004). This approach is particularly suitable for interpretative research, allowing insights to emerge organically from the collected data rather than seeking confirmation of preconceived notions (Corbin & Strauss, 1990). The interviews aimed to centre around the participants' experiences in leading specific projects, with the project itself being the unit of analysis. The objective was to narrow down the analysis and maintain a focused approach, ensuring that the examination remained closely aligned with the specific unit of analysis.

This approach was adopted to prevent the risk of losing focus and to maintain a targeted exploration of the project-related experiences shared by the interviewees.

The main researcher utilized a protocol of interviews with open-ended and expansive questions to facilitate the organic emergence of insights from the data. Despite having an interview protocol in place, the topics discussed did not adhere to a sequential progression. At times, the researchers deviated from the predetermined questions as novel insights captured their attention and prompted a shift in focus. The main focus of the interviews were the topics described in the literature review and their interrelationships: equivocality, governance approaches and project´s success implications. The protocol of interviews is placed in the Annex of this manuscript.

3.2 Sample.

The interviewees were project /scientific leaders of different collaborative projects in the field of Open Innovation and European projects (for instance: H2020 program). Specifically, only one of them has participated in both type of projects. The other 5 interviewees have been participated only on European Projects. They belong to different research field, such as: urbanism (architecture), robotics (engineering), acoustic (engineering), modelling methods (engineering / mathematics) and smart cities/ consultancy (management). Their level of experience varies on each case, but for all of them is higher than 15 years working on R&D projects, thus all of them can be considered as senior project coordinators. The interviewee 1 (robotics) has been the scientific leader in two European projects and he has been part of more than 5 collaborative projects. The interviewee 2 (acoustic) has participated in more than three collaborative projects and he has been the WP leader in one of them. The interviewee 3 (modelling methods) has been participated in three collaborative projects, being the scientific coordinator in one of them and the WP leader in the other ones. The interviewee 4 (urbanism) has participated in more than 5 European Projects, being the scientific leader in more than three of them. The interviewee 5 (smart cities) has experience +20 years in consultancy, leading collaborative projects in the private sector (open innovation) and in European projects. Finally, the interviewee 6 (signalling processing) have participated in more than five H2020 projects, leading 2 of them. In this sense, their expertise provides valuable insights for the research as they have been not only participants but also, leaders of the projects. The following Table 2 summarized the data collection sample:

Interviewee nº	Role of the interviewed	Project name	Project type	Country
1	*Project coordinator*	*Alfa / Beta / Delta*	*H2020*	*Spain*
2	*WP leader*	*LOCUTIOS*	*Seventh framework*	*Spain*
3	*Scientific leader / WP leader*	*GAMMA*	*H2020 / Seventh framework*	*Spain*
4	*Scientific leader*	*OMEGA / EPSILON*	*H2020 / Seventh framework*	*Spain*
5	*Project Manager*	*IBM*	*Open Innovation*	*France*
6	*Project coordinator*	*LOCUTIOS.*	*H2020*	*Sweden*

Table 2: Summary of research sample / Section I

3.3 Data analysis.

The data analysis followed an iterative and inductive approach, involving the systematic examination of the collected data, followed by a comparison of the emerging findings with existing literature (Corley & Gioia, 2004). 5 out of 6 interviews were recorded and transcript using NVivo software. The coding process encompassed two distinct analytical procedures: first-order analysis and second-order analysis. During the first-order analysis, patterns were identified through sense-making, while maintaining a strong connection to the data itself. In this stage, codes emerged spontaneously, without a pre-established structure, allowing for a flexible and open exploration of the data (Corbin & Strauss, 1990). The second-order analysis involved another systematic round of coding and the results are a series of themes that gathered related open codes. Themes are clearly distinct from codes; codes are precise and succinct, whereas themes can be considerably more complex and can synthesize a multitude of codes in order to theoretically elucidate phenomena (Thompson, 2022). In this 2nd-order analysis, we are now firmly in the theoretical realm, inquiring whether the emerging themes suggest concepts that might help us describe and explain the phenomena we are observing. In this sense, through a process of reading the list of open codes and pooling the codes into themes, the results are organized in a set of six themes that are highly related to the framework proposed in the literature review. The organization of the results into themes associated with the initial framework enables us to present a refined iteration of it, which will serve as the foundational point for section II.

4. Results.

The findings are categorized into *themes* based on their alignment with the framework proposed in the literature, as well as additional emergent topics that arose from the data through inductive analysis (Corley & Gioia, 2004). This organization facilitates a comprehensive exploration of both the pre-established framework and the fresh insights that emerged organically during the analysis process.

This section is organized as follows: starting with an improved description of our research phenomenon, collaborative project. This reflection helps us to provide an improved understanding of the nature of the project. Then, the initial three themes (4.1 to 4.3) present a reflective discussion regarding topics previously addressed in the literature review, project success, equivocality and the interplay between equivocality and governance. These insights provide empirical evidence that improves the comprehension of the established theoretical constructs and their interconnections. Conversely, the final three themes (4.4 to 4.6) have surfaced organically and inductively during the interview process. Their inclusion in the discussion aims to refine the initial framework and shed light on more specific aspects related to the research topic.

4.1 Introduction.

First, a relevant issue to consider is about the sponsoring organization and the level of technological maturity of the results of the project. Collaborative projects can be sponsored from either private or public organizations (Klessova et al., 2020). In both cases, a consortium of partners comes together to address a common challenge. However, the dynamics within each consortium can vary depending on the type of sponsoring organization. The interviewee 5 has participated in both types of projects and he highlighted the different nature of each one of them.

On the one hand, private organizations with specific market needs often engage in collaborations with various partners, including suppliers, universities, and others, to address those needs. In this scenario, an incumbent company typically provides most of the project's funding and stands to gain the benefits from the project's outcomes (Gambardella & Panico, 2014). While their market needs may be (to some extent) well-defined, they may have limitations in terms of resources and capabilities. Therefore, they actively encourage collaborations to foster the innovation process, reduce time to market, and share costs and risks (West & Bogers, 2014). These are usually known as “open innovation projects” (Henry W. Chesbrough, 2004).

On the other hand, collaborative projects can also be funded by public organizations, such as the European Commission (EC), through well-known programs such as the Seventh Framework or the H2020 (González-Piñero, Páez-Avilés, Juanola-Feliu, & Samitier, 2021). In these projects, organizations

from various sectors and fields come together to propose project ideas, which are then submitted for evaluation by the European Commission. Following a thorough process of analysis and assessment, the EC approves or rejects the proposals, providing financial resources to each partner to formally initiate the project. In this context, the size of the network, the type of technology, and the management approach may vary depending on the specific proposal. However, the EC retains the role of supervising the project's progress and remains the primary beneficiary of the project's outcomes (Enger & Gulbrandsen, 2020). It delegates the responsibilities of scientific coordination and project coordination to different partners involved in the collaboration.

Both types of projects can be considered as collaborative innovation projects. However, they face very different challenges because their nature is different.

> "*The open innovation projects are aircrafts that try to link two points in the shortest time possible. The European projects are aircraft carriers that carry on several smaller aircrafts, but at the end, all of them arrive at the same point together, following a slower development rate and rigid contractual conditions, limited by the EC*" (interviewee 5).

Each typology of project possesses distinct objectives, characteristics, and limitations. Open Innovation projects, for example, address a specific company´s need by investing in the development of potential solutions through partnerships. The project's scope may evolve throughout its lifecycle, as well as the composition of participating partners. On the other hand, European projects funded by the European Commission are designed to accelerate the transfer of technology from universities to society, promoting the practical application of research outcomes (Arranz & de Arroyabe, 2008). The consortium of partners is defined at the beginning of the project and changes in the network structure are not common (Enger & Gulbrandsen, 2020).

> *"In European Projects, the consortium of partners is maintained during all the project, except for unusual cases such as bankruptcy or something like that. However, the level of implication of partners varies a lot during the project, and that is something that you cannot foresee"* (interviewee 1).

Then, collaborative projects can be categorized according to their TRL (Technology Readiness Level) (Klessova et al., 2022). According to this category, there are 9 levels of technology development (TRLs), the lowest are more related to basic (scientific) research and the highest are related to a market application. The objective of European projects is to fund projects that help "transfer" technology from one level to the next one.

"*In European projects you go from one TRL level to the next one, for instance, from 2 to 3, or two levels as much, from 5 to 7 for instance*" (interviewee 1).

The nature of a project varies depending on the Technology Readiness Level (TRL) of the product. Lower TRLs typically correspond to basic scientific research, often referred to as collaborative research projects (vom Brocke & Lippe, 2015). On the other hand, higher TRLs are associated with leveraging existing knowledge for more commercial or market applications (Chiesa & Frattini, 2007). The complexities, network structures, and challenges differ based on the TRL of the product, making it challenging to draw valid comparisons between them.

Therefore, it is essential for the research to clearly define the boundary conditions and indicate the extent to which the results can be generalized, considering the specific project type according to the funding organization and the TRLs score.

4.2 Theme#1: Project success in collaborative projects

As highlighted in the literature review, two primary paradigms have been identified: one emphasizing the successful delivery of outcomes (value perspective), and the other prioritizing the efficient development of outputs (Padalkar & Gopinath, 2016). The data collected provides evidence for both trends.

"*I only talk about my experience on collaborative projects, I am not able to quantify the two realities. The first one, there are projects that deliver what they promised, accomplishing and justifying everything, such as the scope (output) and the resources they required (cost). But at the end, they do not provide anything new to the stakeholders, the scientific community or the market. On the other hand, I have participated and also, I know some cases in which the partners invested much more resources than they were allowed to. But at the end, based on their high implication, capacity and dedication, they ended up the project with valuable outcomes that represent a real contribution to the scientific community or to the stakeholders*" (Interviewee 4).

"*Considering the GAMMA, there were more than 25 partners, and none knew what the other ones do. Each one of them were focussed on delivering what it was supposed to deliver. I don´t have any idea if someone is perceiving the benefits of the outcomes produced to the project. But, I think all the partners dedicated the time and resources agreed on the contract to deliver "something"; What we delivered is providing a differential value to the society? I have no idea; and I don´t think so*" (interviewee 3).

"*If you ask to me, I have to say we have spent much more resources than we expected to and also, more than what we were allowed to. But at the end, we were able to finish the project on time, and accomplishing 98% of the agreed scope. If we consider the value that we added to the scientific community, we have to admit that the LOCUTIOS was an example of success. A few years after its completion, there are several citations of this work, there is a specific track in congress that follows this new technology. We generated a new body of knowledge that did not exist at the European level. This project has been a milestone in this type of FET (future emergent technologies). With this project´s outcomes, in the future there will be market-applications in the biomedicine, eGmes, etc. We created the basis for all of them*" (interviewee 2).

"*If we follow the number of citations that the EPSILON project has, it can be considered as one of the most successful projects developed for us, according to the scientific recognition. I know there are also several projects that continue the line that we had created, even though it is not associated with citations. But, I (as a scientific coordinator) and the main partners, have dedicated more resources (extra hours) that had not been economically compensated*" (interviewee 4).

The two research streams are clearly evidenced on the interviews. There are projects such as the GAMMA in which the partners dedicated the resources a priori allocated, in order to deliver the initial scope (output) on time. In this case, according to the efficiency perspective, it might be considered as a success. But there is no evidence that the outcomes of the project are being perceiving by the stakeholders (European Commission) in a long-term process of value realization (H. Smyth et al., 2017). Based on the value paradigm (value added by the outcomes), this project cannot be considered as a success, according to the data collected.

On the other hand, projects such as the LOCUTIOS or EPSILON, according to the efficiency perspective, the key partners had to spend more time and resources than they were allowed to. This extra time/ cost had not been compensated by the sponsor (European commission). However, they were able to deliver what it was expected (scope) on time, but by investing more resources (cost). According to the value perspective, both can be considered as a successful project, because in both cases, there are several organizations that are perceiving and capitalizing their outcomes. For instance, by reaching a high number of citations, getting recognitions and awards by the scientific community (Chiesa & Frattini, 2007).

The analysis conducted in theme #1 is not intended to generalize about a phenomenon or to generate additional academic contributions to the field. Instead, its purpose is to provide supporting evidence for the issue that has already been identified in the existing literature.

4.3 Theme#2: Equivocality as the main challenge in collaborative projects.

The interviewees were requested to identify the primary challenges they encountered while working on collaborative projects, aiming to compare theory with their practical experience. The majority of the responses concurred that dealing with equivocality is the central issue in collaborative projects.

> "*The main issue in collaborative projects is that each partner has their own background, and their own way of perceiving information*" (interviewee 1).

> "*The great deal in these projects is that you gather researchers from very diverse fields, and none knows what the others do. Regarding a specific reality of the project, in terms of facts, they can understand them in a very different way. This highlights the relevance of the scientific coordinator, that has to link all the knowledge fields together for the sake of the project*" (Interviewee 3).

However, the reasons that drive equivocality issues were not only associated with the diversity of backgrounds. Also, they have mentioned the coexistence of diversity of interests within a project as one of the main sources of equivocality.

> "*Each one of the partners has their own values and their own interest on the project. We have done great collaborations with some partners and successful results, but we have found partners who tried to devote as little time as possible to the project. It occurs due to the moral values of each one. There are partners that really want to develop something innovative, and their level of involvement is high, and also, there are partners that dedicate the minimum time possible, because they only want to justify their funding. Each one interprets the reality in different ways*" (interviewee 4).

> *"There are partners that want to keep the ordinary activities fund, but also, there are partners who want to develop novel research, novel scientific work"* (interviewee 6)

Aligning diverse backgrounds and motivations increases the complexity of collaborative projects, and one of the primary symptoms of such diversity is equivocality. Consequently, misunderstandings can have both positive and negative implications, making equivocality a double-edged sword.

> *"If divergencies are found in the project objectives, it is a problem. It´s mandatory for all the partners to understand the same project objectives. However, if divergencies are found in how to solve the problem, that would be beneficial for the project. If the project allows to propose different formulas to reach the same objective, that would benefit the project a lot. But the objective should be clear for everyone" (..) "If there are misunderstandings about the objective, it is a real and relevant problem. If there are misunderstandings about how to solve the problem, that would be beneficial".* (interviewee 1).

4.4 Theme#3: The interplay between governance approaches and equivocality.

As it was hypothesized in the literature, the implications of equivocality in project results are moderated by governance approaches, actions and behaviours. Concepts such as trust, communication, leadership and personal interactions (relational governance) have emerged as the main mechanisms to deal with equivocality.

> "*The main action we can do to reduce these diversities of interpretations, is to meet up. You need to know the people who is working with you, create relationships and by doing so, you will start sharing and understanding interpretations. Once you face an issue, you would easily solve it because you know and trust the people who work with you*" (interviewee 1).

Research has shown that personal interactions and frequent communication play a significant role in fostering trust among partners (Davenport et al., 1998). Within exploration projects, the increasing reliance on trust among partners correlates with improved project performance (Arranz & de Arroyabe, 2012). Establishing trust among partners facilitates open and secure discussions stemming from diverse perspectives on how to progress. Conversely, a lack of trust between partners may encourage individual behaviors rather than collaborative efforts (Malherbe, 2022). In such scenarios, when differing viewpoints coexist, partners may prioritize safeguarding their own interests over achieving a common goal. Building trust requires substantial investment in time and resources throughout the project, emphasizing that communication and personal interactions serve as pivotal drivers for trust-building, rather than being assumed or inherent (Davenport et al., 1998).

Then, the project leadership emerges also as a vehicle to align partners and reduce misunderstandings.

> *"The role of the coordinator is relevant to align all the parties. You need to gain the respect of the partners and that would enable to gain their trust. And then, If you get all the partners on board, overcoming misunderstandings becomes much easier, as all the partners respect and trust you"*. (Interviewee 4)

> "*It is the role of the coordinator to align all the expectations and understandings. During the project, you need to gain the partner´s respect, and afterwards, trust will emerge. If you don´t do that, would be merely impossible to get all the partners on board and to create a real collaboration. In other words, each partner will work in their own task, and there would be no collaboration"* (interviewee 2).

However, not all the leadership styles might be suitable to deal with collaborative projects.

> *"The leadership doesn´t work based on authority, because everything is subjective and subject to interpretation. A WP (work package) leader can conceive as a good output 1 article and other one can conceive the same with 10 articles, and both are ok. In this sense, if leadership would be ruled by authority, all the project will explode, mainly due to EGO, different implications, etc." (…) "Our role (as coordinators) were to harmonize the workflows between the different groups"* (interviewee 3)

Trust does not solely stem from positive relationships between partners (horizontally); it is also intertwined with the authority wielded by project coordinators or managers. Collaborative projects operate within highly uncertain contexts, where managers often lack comprehensive information for precise estimations and predictions (Klessova et al., 2022). Consequently, they frequently face decisions crucial to the project's continuity and the interests of involved partners, despite having limited insight into the implications of these decisions. In this challenging environment, positive leadership behaviors become instrumental. They help partners trust project managers, especially when navigating conflict-ridden decision-making processes (Gulati & Nickerson, 2008). Moreover, partners' trust in their managers aids in minimizing misunderstandings stemming from diverse interpretations. Positive leaders excel in aligning a diverse array of partner perspectives towards a shared and unified objective.

Sharing similar scientific interest and mutual commitment with the project also emerged as a vehicle for reducing misunderstandings, creating trust between partners.

“If both parties are willing to cooperate, they will overcome these misunderstandings easily and that is really nurturing. Science is the common language" (Interviewee 3)

“When you respond according to the expectations you start gaining trust with the other partners. Then, this trust enables communication spaces, required to discuss topics and reduce misunderstandings. But, everything starts when you show results, when you show you are committed with the project”. (Interviewee 2)

Therefore, the implications of equivocality in project results are moderated by governance approaches. Even though relational approaches through personal exchanges, informal communication, trust or leadership emerge as the main vehicle to deal with equivocality, formal governance also might contribute to reduce or exacerbate misunderstandings.

4.5 Theme#4: Uncertainty in collaborative projects.

During the interviews, a theme that emerged spontaneously, not originally included in the protocol, was the recognition of inherent uncertainty in collaborative projects. Dealing with equivocality was one of the main issues identified in the interviews, as well as dealing with unexpected issues derived from the high uncertainty of these projects. This issue was particularly evident in collaborative projects focused on developing scientific knowledge or conducting basic research (Lower TRL).

"In the world of ideas, everything works. But reality is revealed when problems arise, and no one knows exactly what or how to do." (...) "And in those cases, we fared well because we had solid knowledge foundations that enabled us to face issues derived from uncertainty” (Interviewee 2).

"The important thing is to strive to reach the initial objective, but the key is to understand that many unexpected things can happen, forcing you to adapt. Change management becomes crucial. It's about finding ways to confront the unknown and still seek solutions to try to achieve the initial goal" (...) "It's like driving and suddenly the road is cut off. You have no choice but to find a way to reach the destination. You have to keep going, you can't stop because if you stop, the project fails." (...) "What makes it more complex is that it cannot be predicted. At some point, you have to take a risk by choosing a path without knowing if it will lead you to your destination." (...) "In these unexpected situations, the role of a leader is crucial to guide everyone in a direction. However, the leader must earn the respect and moral authority of the entire group to make decisions about which way to go.". (Interviewee 2).

*“The risk in these projects is extremely high, and failure is the most common outcome. When you have Low Technology Readiness Levels (TRL), proposals are often very ambitious, resulting in a high failure rate” (*Interviewee 2).

"In research projects, due to the inherent scientific uncertainty, you come across unexpected things. At the beginning, you might know the project strategy and how to tackle problems. However, once the project starts, you start finding many things you could not estimate. You know what has happened and where you are, but you have no idea where to go or how to proceed. That's why they are research projects, because you don't know what might happen" (Interviewee 3).

“*You sort of are expected to deliver something that is in some sense predictable, which kind of runs against the grain of what it's usually considered to be basic research*” (interviewee 6).

In exploratory scientific projects, the implications of uncertainty are even greater compared to projects that are closer to the market or focused on knowledge exploitation (vom Brocke & Lippe, 2015). Consequently, these projects are highly susceptible to encountering unexpected challenges stemming from their inherent uncertainty. As a result, the success of these projects is strongly linked to their ability to effectively address unforeseen issues while continuing to develop outputs and deliver value (Wied et al., 2020).

4.6 Theme#5: Couplings in collaborative projects.

In collaborative projects, various types of couplings or interconnections exist between different teams. The term coupling describes the presence of joint activities and exchange of knowledge between independent organizational actors and can be described based on intensity and the strength of the connection (Klessova et al., 2022). The nature and intensity of collaboration and interactions are contingent upon the level of couplings.

"You have three levels: the macro level, where you see the overall vision among partners; then you have the micro level, either among partners internally or between work packages. In this level, you have to adjust with the partner, there has to be a strong interaction, a clear direction, and be highly aligned. Then there's the micro-micro level, which is internally within the team in your own organization" (Interviewee 2).

The nature of cooperation varies in each case. At the strategic level, the team´s leaders engage in discussions on top-management matters such as project objectives, resource allocation, and sponsor

communication. Interactions at this level are less frequent and intense. In the couplings at operative levels, which encompass interorganizational relationships between or within work packages, interactions are characterized by higher frequency and intensity as partners engage in discussions regarding both managerial and technical issues. At this level, partners must align their expectations and also, their working methodologies, backgrounds and reduce knowledge gaps. These interactions are characterized by more frequency and intensity than strategic ones. At the micro-level, team members within each organization collaborate and coordinate their activities daily. These dynamics are commonly explained by traditional team management models.

> *"You have these different levels, and within each space, you have leadership. So, there was a structure with a different hierarchy depending on the partners".* (Interviewee 2).

This is one of the most significant challenges in collaborative projects. Managerial matters are addressed at the executive level, where partner alignment through a common objective plays a crucial role. However, the intensity of collaboration intensifies at the couplings, where the diversity of partners and their interests collide not only in managerial aspects but also in operational and technical aspects, thereby increasing the complexity of interactions (Klessova et al., 2022).

Examining the distinct levels of analysis regarding interorganizational relationships among partners is crucial for understanding the collaborative capacity of a project and their success results. Differentiating the unit of analysis either at the project level or at the couplings level becomes relevant for the research, as equivocality situations might play a different role in each level of analysis.

4.7 Theme#6: The emergent role of organizational learning

> "T*he key success factor is to gain the respect and authority of the partners (as a coordinator), since the first minute until the end of the project, and that creates trust among all the consortium of partners*" (Interviewee 4).

While this statement may be associated with leadership or trust (relational governance), it also holds implicit significance for the team's ability to learn how to collaborate effectively (Bäck & Kohtamäki, 2016). Given that partners possess diverse backgrounds and varying interests in the project, aligning their expectations becomes a challenge, especially in the absence of a customer-supplier relationship and prior collaborative experience. Trust cannot be assumed; rather, it necessitates time and resources to be cultivated throughout the project (Davenport et al., 1998). This calls for partners and coordinators to develop mutual understanding and foster relationships to be able to develop joint

outputs. Learning capabilities enable partners to transfer individual knowledge into a joint knowledge output and to generate trust among themselves (McClory, Read, & Labib, 2017).

This theme emerges as a further interpretation of the previous ones. Different learning behaviours and actions take place according to the coupling either at the strategic level, interorganizational or intra-organizational level.

> *" The degrees of intensity are gradually relaxing. The closer you are to your partner, the stronger the learning is " (*Interviewee 2).

Bridging knowledge gaps among partners without sharing previous experience seems also a matter of learning. And it is expected that as far as the project evolves, the learning capacity enables teams to bridge gaps and improve collaboration.

> *"it was a matter of learning. It was like the intensity of the collaboration gradually increased toward the end of the project and say, when we saw that the deadline was approaching, it was like an incentive"* (Interviewee 6).

The concept of learning emerged inductively from data, as an interpretation of the researcher. It was not considered initially in the model, but there are signals that make evident this plays a crucial role in collaborative projects. Further research is required to clarify the role played by learning on the evolving interdependency between equivocality and governance.

5. Discussion.

The part I of the research aims to elucidate how the interplay between equivocality and governance affects project results, according to the success perspectives based on the efficiency or value paradigms. An initial framework was proposed in section 2.8 aimed to provide the blueprint to guide the research endeavour. A round of interviews (6) were taken with project managers whose focus was to increase the understanding of the phenomenon with specific focus on the interplay between the three constructs. The result of this part I is an improved version of the initial framework complemented with insights obtained inductively from data.

The insights obtained were categorized into themes based on different topics. As suggested, managing equivocality has been recognized as one of the most challenging aspects in collaborative projects (Rönnberg Sjödin et al., 2016). Many of the issues discussed in the literature were corroborated in the interviews with project leaders. However, a novel insight resides on the role played by equivocality as a double-edge sword (Eriksson et al., 2016).

> *"If there are discrepancies in the project objectives, it becomes problematic. It is essential for all partners to have a shared understanding of the project objectives. However, if there are divergences in how to solve the problem, it can actually be beneficial for the project. If the project allows us to propose different approaches to achieve the same objective, it can greatly benefit the project. Nonetheless, the objective itself should be clear and understood by everyone involved"* (interviewee 2).

This insight rather than contraposing the existent perspectives of the dual implications of equivocality on the project results (Eriksson et al., 2016), it offers a more nuanced and detailed description of the nature of this phenomenon. Equivocality in goal definition can lead to partner confusion, tensions, and frustrations, as there is no clear guidance on the desired direction. This issue can have additional negative implications, such as challenges in resource allocation and partner coordination (Frishammar et al., 2011). However, if there are instances of equivocality regarding how to proceed, where different approaches can still lead the project to similar outcomes, equivocality can also be associated with positive implications in the project results. In light of this reflective process, our focus shifts towards equivocality situations pertaining to "how to proceed" rather than "what is the objective" (Patel et al., 2018). In other words, we emphasize equivocality in relation to processes rather than objectives.

Secondly, confirming the theoretical assumptions outlined in the initial framework, the impact of equivocality is highly influenced by the governance approaches adopted to address it (Morandi, 2013). Relational approaches, in particular, have been highlighted by interviewees, as these enable partners

to foster trust among themselves (Marcandella & Guèye, 2018). When trust is established, potential misunderstandings can be more easily resolved (Ruangpermpool, Igel, & Siengthai, 2020). In other words, relational governance can moderate the implications of equivocality (either positive or negative) in the project results (Morandi, 2013). It has also been discovered that governance can exacerbate equivocality issues, not only mitigate them. When there is a lack of strict monitoring, partners may focus solely on their own tasks instead of fostering collaboration and working towards common goals. In collaborative projects that involve multiple couplings, the absence of monitoring and control can give rise to situations of high equivocality. In this sense, governance approaches were identified as means of managing equivocality, but paradoxically, these could also exacerbate equivocality situations.

This relationship is best described as non-linear, characterized by cause-effect non-linearity[1] and mutual causality[2], rather than simplistic cause-effect relationships (E. Daniel & Daniel, 2019). In the literature is initially proposed this issue, and the data obtained through interviews not only validated this assumption but also provided additional empirical insights into this relationship. Even though these cases provided some insightful evidence of the interdependency between equivocality and governance, deeper research is required to provide more clarity of the evolution of this interrelationship.

The second topic to discuss is “project success” (Ika & Pinto, 2022). Based on the interviews, the evaluation of project success, whether based on efficiency or value perspectives, is a relevant issue in most projects. Moreover, this evaluation is closely linked to each of the interests of the project partners. Some partners may prioritize delivering valuable outcomes, while others may focus on developing outputs in the most cost-efficient manner, utilizing minimal resources. Strategic decisions rely on how the partners measure project results, which can vary depending on the partners' expectations and their impact on the project. Given the diverse range of interests and expectations in

[1] The concept of "non-linearity" in relationships between two or more variables is derived from complexity theory (Dent, Bacon, Russ Marion, Tom, & Koch, 1999). In the book written by Dent et al., (1999) p. 23, the analysis of the two types of relationships (lineal and non-lineal) is graphically explained:
“*Non-lineal interaction mechanisms arise naturally in far-from-equilibrium processes. Linear relationships between elements are so called because they can be described with a straight line. This directly proportionate relationship between two quantities defines linear relationships. Because the interaction between elements is consistently additive, long-term predictions of their behaviour are possible. In non-lineal relationships, the relationship between variables is disproportionate. Feedback results from non-linear processes, as process outcomes trigger additional changes that are impossible to predict. If accurate mathematical descriptions of initial conditions were available, it would theoretically be possible to accurately describe non-linear processes. Since they are not, however, complex non-linear processes remain unpredictable*”

[2] Maruyama (1963) considers mutual causal systems to be “*those whose elements influence each other, either simultaneously or alternating”*. Consequently, these concepts may require us to move beyond linear causality to adopt a new, more complex and holistic paradigm. In sum, a paradigm shift, from lines to circles.

collaborative projects, there is a corresponding variety of what success means for each partner, either related to the efficient development of outputs or valuable delivery of outcomes.

Rather than filling the gap presented in the literature, the empirical insights indicate that the implications of the problem are even more significant. The diversity of success perspectives not only exists as a matter of the evaluation of the project results, which is the primary unit of analysis (Ika & Pinto, 2022). But it is also related to the partner´s perception of success, based on their interests and involvement in the project. This adds a managerial challenge since decisions are made collectively by the partners. Each partner perceives the implications of these decisions on the project results differently, as project success hold varying meanings for each of them, making the partner´s alignment -either with the efficiency or value perspective- more complicated.

The third topic to consider is managing uncertainty, and it emerged inductively from data.

> *"The important thing is to strive to reach the initial objective, but the key is to understand that many unexpected things can happen, forcing you to adapt. Change management becomes crucial. It's about finding ways to confront the unknown and still seek solutions to try to achieve the initial goal"* (Interviewee 2)

Understanding the evolving interrelationship between equivocality and governance is a promising research avenue, with clear implications in the project results. However, studying these relationships in moments where unexpected issues arise, becomes even more relevant. In projects characterized by high uncertainty, the team's ability to navigate and adapt to unforeseen threats becomes crucial, as these challenges are inherent to the nature of the project (Yang et al., 2022). When confronted with an uncertain and unforeseen situation, equivocality might be exacerbated. Each partner brings their own background and interests to the project, leading to different perceptions and interpretations of the uncertain situation based on their own perspectives. This can give rise to misunderstandings, not only in evaluating the reasons behind the unexpected issue but also in determining the appropriate course of action to overcome it (Burström & Wilson, 2018). Thus, during perturbations caused by unknown situations, equivocality issues may arise and being exacerbated.

Consequently, studying the implications of the interrelationship between equivocality and governance during perturbations originated from uncertain situations is highly relevant. To further advance research in this area, it would be appropriate to narrow the focus from the overall project lifecycle to specifically examine situations resulting from unexpected issues (Fey & Kock, 2022). This decision is motivated by the fact that collaborative projects are particularly prone to encountering unexpected issues that amplify equivocality situations and force governance approaches to be adapted

(Naderpajouh et al., 2020). This reflection came from the theme#4 as uncertainty was one of the most referred topics from the interviews.

The fourth topic for discussion is the level of interrelationships between partners. Collaborative projects consist of a series of interconnections among partners at various levels (Klessova et al., 2020). At the highest level, managerial decisions are made between the leaders of the main partners. At the operational level, collaboration intensifies among different organizations, encompassing not only managerial aspects but also technical and methodological challenges (Klessova et al., 2020). The issues of working with a diversity of knowledge backgrounds become more evident at this level, as partners need to exchange knowledge, information and results, which may lead to salient tensions and conflicts. Lastly, despite that collaborative projects require collaboration with external parties, a significant amount of work is also carried out internally by each organization. At this level, collaboration within a single organization is widely addressed in theories of intra-organizational team management, such as the Tuckman model and others (Tuckman, 1965).

It is important to reflect on this aspect as the nature of interactions and collaboration depends on the level of analysis (McClory et al., 2017). Since this research focuses on collaborative projects, the analysis is limited to the first and second levels: collaboration at the strategic level (top level) and the interconnections among different organizations at the operational level (couplings). Intra-organizational collaborations are excluded from this research as they do not align with the research's boundary conditions.

Another relevant aspect of the analysis serves as the starting point for the subsequent section, Part II. This insight is derived from the researchers' intuition and was implicitly acknowledged by the interviewees. It pertains to the ability of interorganizational teams to learn how to collaborate together (Huikkola et al., 2013). Collaborative projects are composed of diverse partners with various backgrounds and interests, who lack prior experience working together but are brought together to tackle an ambitious and ambiguous problem (Calamel et al., 2011). Implicitly, the partners must learn how to collaborate in order to achieve a joint output (Bäck & Kohtamäki, 2016). Furthermore, these learning capabilities are developed throughout the project lifecycle, both at the strategic level (top level) and at the operational level within each interconnection (coupling), necessitating distinct learning processes for different levels (McClory et al., 2017).

Additionally, we hypothesize that learning behaviours can assist the interorganizational teams in overcoming equivocality situations through governance implementations (Marcandella & Guèye, 2018; Solís-Molina et al., 2021). To grasp the intricate nature of the problem, it is essential to consider the interplay between equivocality situations, governance, and also the learning behaviour of the

involved organizations. This approach is further elaborated upon in the subsequent sections and represents the central contribution of this research.

Lastly, collaborative projects constitute a distinct project typology characterized by specific features that facilitate the definition and characterization of the subject. These characteristics were described in the initial section (2.2) of the literature review. However, subcategories of collaborative projects emerged from the data, contributing to the refinement of the research's boundary conditions. In this sense, the diverse typologies of collaborative projects, determined by their Technology Readiness Level (TRL) and the sponsoring organization, constitute a boundary condition that deserves careful consideration.

The type of organization providing the majority of investment plays a crucial role in shaping the project's governance structure, contractual agreements, and problem-solving approaches. Additionally, the nature of the project is influenced by the TRL of the product involved (Arranz & de Arroyabe, 2008). Projects with higher TRLs are typically focused on implementation, exploitation, or market-oriented objectives, aiming to facilitate the exploitation of existing knowledge (Chiesa & Frattini, 2007). On the other hand, projects with lower TRLs are often centred around basic research or exploratory endeavours (vom Brocke & Lippe, 2015). These projects are characterized by heightened uncertainty and, consequently, higher rates of failure. In this research, the focus of analysis will be on collaborative exploration projects, specifically those aimed at advancing scientific knowledge through collaboration among various stakeholders (Arranz & de Arroyabe, 2008; Chiesa & Frattini, 2007). This decision is motivated by the significant levels of uncertainty and failure rates commonly observed in such projects, which necessitate a high degree of collaboration (vom Brocke & Lippe, 2015).

The next Table 3 summarized the main topics reflected in the discussion and the initial framework refined after the round of interviews. The Figure 4 represents the refined framework originated in the discussion of this section.

Concept	Initial framework proposal	Refined framework proposal
Interrelationships between equivocality and governance	Mutual and non-lineal relationship between both constructs during the project lifecycle.	Mutual and non-lineal relationship between both constructs during moments of instability. Special focus on situations of equivocality related to processes rather than objectives.
Project success evaluations	The implications of equivocality and governance into the efficient	The coexistence of both paradigms remains in the model, but rather than focussing on results, the

	development of outputs or valuable delivery of outcomes	framework moves to consider how both paradigms affects decision-making process among partners.
Uncertainty management	No special consideration on the implications of uncertainty into collaborative projects.	As collaborative projects are embedded in uncertain contexts, the focus of analysis moves from the overall lifecycle to situations of high instability produced by unexpected issues (perturbations).
Level of analysis.	No special focus was given to the different levels within collaborative projects.	Special considerations should be given to the level of analysis in case studies. Multi-level analysis includes strategic and operative levels and interorganizational relationships.
The role played by organizational learning	No special focus was given to the teams´ learning capability.	We hypothesize that organizational learning is a relevant construct to study during perturbations produced by unknown issues.
Collaborative projects	The initial framework does not demarcate between different typologies of collaborative projects.	Narrow down the focus into collaborative exploratory projects / Low TRL, sponsored by public organizations.

Table 3: Refined initial research framework. Part I

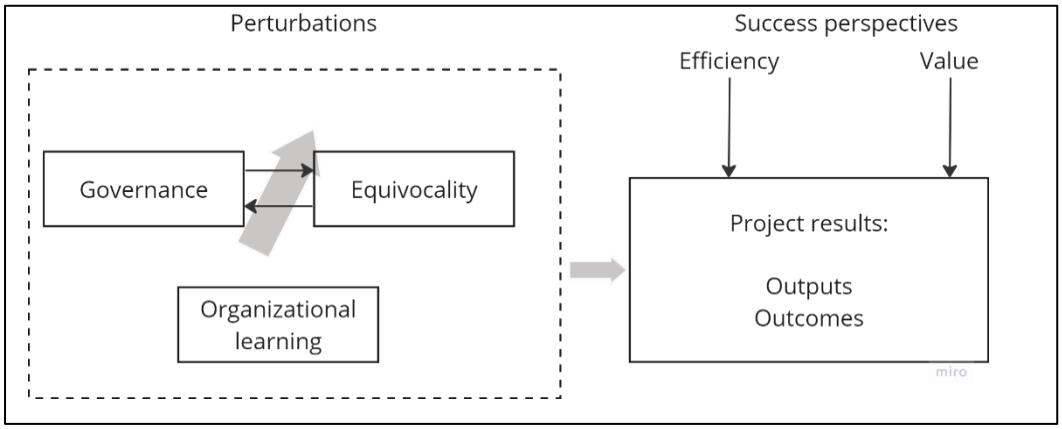


Figure 4: Refined research framework. Part I

6. Conclusion.

The primary objective of the initial part of this research was to bring clarity to the three key constructs under investigation: project success, equivocality, and governance. Through the literature review, we were able to shed light on the major research streams associated with each construct. It is important to note that equivocality and governance are intricately linked through feedback loops (Majchrzak et al., 2015). To comprehensively capture the dynamic evolution of this interrelationship and its implications on the project results, we proposed a research framework. Additionally, we considered

two streams of project success, recognizing the lack of consensus within the scientific community regarding the definition of success at the project level (Ika & Pinto, 2022).

An exploratory study was conducted with project managers to gain further insights into the initial framework. The analysis of the collected data revealed relevant concepts, including the implications of uncertainty, project´s boundary conditions, and the moderating role of organizational learning. Consequently, the Part II of this research will delve into the dynamic evolution between equivocality and governance during periods of instability (perturbations) caused by the inherent uncertainty of collaborative research projects. The focus of the study will be narrowed down to basic research projects (exploratory projects) due to their higher failure rates and increased likelihood of facing disruptions stemming from unknown issues. Lastly, it is hypothesized that organizational learning facilitates interorganizational teams in overcoming perturbations. The project success is closely aligned with the learning capabilities of the organizations involved in (Solís-Molina et al., 2021). Part II will provide an in-depth analysis of the role of organizational learning within this context.

Part I of this research concludes with a refined version of the initial framework, which was initially derived from existing literature and further enriched with empirical data. This section serves as the theoretical underpinning for the subsequent section, where the research's contribution will be elaborated upon.

Part II. Understanding resilience in collaborative research projects.

7. Introduction

Bringing together actors from different knowledge fields, scientific schools and cultures provides a rich environment for the development of innovative products, knowledge, and technologies (Nisula et al., 2022). However, this collaborative environment presents significant managerial challenges for the partners involved in the projects (Derakhshan et al., 2020). This is basically because a diverse range of knowledge backgrounds, working methodologies, and interests coexist, all aiming to develop novel, complex, and innovative outputs (Klessova et al., 2022), thus increasing the level of uncertainty, complexity, and ambiguity within the project (Burström & Wilson, 2018).

In this increasingly uncertain environment, effectively managing perturbations arising from unforeseen adversities becomes inevitable, and the project's success significantly relies on the team's capability to successfully overcome them (Fey & Kock, 2022; Yang et al., 2022). Such disturbances require the partners to respond, adjust and stabilize the project; otherwise, project failure becomes a likely outcome (Wied et al., 2020). In this sense, exploring how a team can effectively manage and recover from unforeseen disturbances is a promising and an unexplored area of research (Naderpajouh et al., 2020).

While project management literature extensively addresses uncertainty, the focus has primarily centred on risk management plans (Naderpajouh et al., 2020). These approaches assume that managers possess the ability to estimate probabilities and consequences of known threats (Rahi, 2019). Nevertheless, a project's success is contingent upon its aptitude to overcome disturbances arising from unexpected events (Wied et al., 2020), rather than solely relying on accurate estimations of known potential events (Yang et al., 2022)

While empirical studies, such as those conducted by Wied M. et al. (2020) and Fey & Kock (2022), have explored specific actions or behaviours to address unexpected disruptions, a more comprehensive perspective that enables to understand “how” a project overcomes perturbations remains necessary and reveals new research avenues (Naderpajouh et al., 2020; Yang et al., 2022). This study aims to fill this gap by analysing the complex interrelationships between relevant constructs during perturbations: equivocality and governance, and the moderating role played by organizational learning. The objective of this study is to increase the current understanding about how a collaborative project is able to overcome perturbations, focused on the dynamic interplay between the three constructs, equivocality, governance and organizational learning, being their implications relevant during times of disruptions. This topic is relevant to study due to the considerable impact that overcoming perturbations has on a project's overall success (Fey & Kock, 2022).

Equivocality is a common issue in all projects. However, during perturbations, equivocality issues may emerge and become exacerbated among partners, whose implications are even more significant due to the high diversity of partners and interests involved in a collaborative project (Patel et al., 2018). The governance of collaborative projects is designed to enhance the likelihood of project success, whether that pertains to stakeholders´ satisfaction or meeting the triple constraint objectives (Derakhshan et al., 2020). Perturbations usually require governance´s adjustments or adaptations to address unexpected issues (Wied et al., 2020). On the one hand, there are evidence that show that inappropriate governance adaptations might affect the speed and efficiency of the recovery to perturbations, resulting in the termination or even failure of the project (Thomé, Scavarda, Scavarda, & Thomé, 2016). On the other hand, other research show that these changes might also improve the capacity of the project to recover from perturbations (Wied et al., 2020; Yang et al., 2022). In this sense, during disruptions, the adaptation of project governance directly affects how the project overcome perturbations.

Additionally, changes in governance approaches may either produce, exacerbate or reduce equivocality levels (Brun, 2016). The positive or negative implications of equivocality in overcoming perturbations are moderated by the governance approaches applied to manage them (Eriksson et al., 2016), being them also sources of equivocality.

Overcoming perturbations implies changes and adaptations. We aim to understand these adaptation efforts under the lenses of organizational learning (Argyris & Schön, 1996). Diverse learning capabilities enable us to recognize that there are different manners to overcome perturbations. These learning efforts influence how the organizations react to perturbations (Seo, 2020), but also, we claim that the learning might moderate the relationship between equivocality and governance. Different learning behaviours, such as generative or adaptive, might affect how equivocality issues are managed through governance approaches (Mu, Yang, Zhang, Lyu, & Deng, 2021; Senge, 1990).

The literature discusses the relationship between equivocality, governance, organizational learning and the capacity of the project to overcome perturbations in a linear causal manner (Eriksson et al., 2016; Frishammar et al., 2011; Morandi, 2013). In simpler words, cause-effects analysis to understand the relationships between two or more variables. However, in a more unstable environment, such as a perturbation, these relationships become more complex, non-linear and made of loops (Majchrzak et al., 2015). There is a gap in the literature on how collaborative projects can overcome perturbations (Naderpajouh et al., 2020; Yang et al., 2022). This research aims to fill this gap by analysing the complex interrelationships among these three relevant and interrelated constructs during perturbations. In the part I, a list of research questions was proposed as a headlight to guide this research. However, this

section offers a more detailed research question, focused on a more specific research gap where this research aims to contribute.

Refined research question:

> *How do equivocality, governance, and organizational learning interplay together in the process of overcoming perturbations?*

The rationality behind the decision of choosing these three constructs is their relevance during perturbations. Managing equivocality is a central issue in a network of partners and it is exacerbated during perturbations. Changes in governance include the managerial actions, strategies, behaviours and decisions made to navigate disruptions. As perturbations require changes and adaptations in the project, the learning capacity of the organizations also influence how they react and adapt to overcome perturbations. Each of these constructs has a direct impact on an organization's ability to overcome disruptions. Moreover, the literature provides evidence that they are interconnected with one another, exhibiting non-linear relationships (Burström & Wilson, 2018; Majchrzak et al., 2015; Marcandella & Guèye, 2018). One affects the other and vice versa. This study aims to understand the complex relationships between the three constructs, as a manner to improve the existent knowledge about how a project overcome perturbations.

The research framework applied is the complexity theory (Arranz & de Arroyabe, 2008; E. Daniel & Daniel, 2019), with a specific focus on two specific types of complex systems: complex adaptive and generative systems (Anderson, 1999; Chiva et al., 2010). These frameworks provide a solid foundation for comprehending the dynamic interactions and evolution of the three constructs during the process of overcoming perturbations. Their emphasis on mutual causality and non-linearity in relationships enhances our understanding of this complex phenomenon. This section elucidates how some concepts from complexity theory, such as self-organization, self-transcendence, implicate order and edge of chaos provide a well-established framework to understand our research problem. As a result, a preliminary framework is developed in the literature review that combines the mutual interplay between the three constructs with a well-developed framework originated from the complexity theory.

The abductive approach is utilized as a research methodology because it is suitable for providing plausible explanations for how or why (Saetre & Van de Ven, 2021) events occurred and for modelling this reality using previously theorized frameworks (Thompson, 2022). A successful collaborative project, known as the LOCUTIOS project, was chosen as a sample for analysis. A cross case analysis is conducted to study two instances of perturbations within this project, examining the corresponding reactions that facilitated their successful resolution.

The main findings show that the LOCUTIOS project was able to overcome two instances of perturbations but following different learning behaviours. The framework developed in the literature helped to frame the behaviour of each construct during each perturbation. In the first scenario, equivocality served as a catalyst for a knowledge exploration process, where both relational and formal governance approaches complemented each other, and a double-loop learning was observed among the partners. In the second disruption, equivocality acted as a barrier to the knowledge exploration process. Substitution effects were identified between relational and formal governance and single-loop learning was observed among the organizations involved. In this sense, two patterns of reactions that enabled a project to overcome two disruptions have been identified and complex adaptive and generative systems (Chiva et al., 2010) contributed to model the behaviour of each construct in each case.

This part II starts with a literature review of the main research constructs. Special emphasis is given to the interplay between equivocality and governance during perturbation continuing the research line proposed in part I. Then, the concepts of uncertainty and perturbations are clarified to help the researcher focus on specific instances of the project, when this is highly unstable. The upcoming construct introduced in this part is organizational learning, which is a relevant capability enabling a project to navigate disruptions and potentially moderate the relationship between equivocality and governance. The next step is to apply a research framework drawn from complexity theory, complex adaptive and generative systems (Chiva et al., 2010) to understand different behaviours to overcome perturbations. Furthermore, the methodology based on cross-case analysis within a single case study (Yin, 1994) is detailed. Plausible explanations (propositions) are developed in the discussion that enable the increase of understanding about how to overcome perturbations in collaborative projects (Sætre & Van de Ven, 2021). The main contribution of this research work is a conceptual framework sustained in a set of propositions that, based on the interplay of governance, equivocality and learning, explain different patterns of potential reactions to perturbations in a collaborative project.

8. Literature review.

8.1 Collaborative research projects.

Research and innovation have become more collaborative during the last years, specially at the beginning of the century (West & Bogers, 2014). Collaborative R&D projects might be considered as a subset of open innovation project (Enkel, Gassmann, & Chesbrough, 2009). Collaborative research projects are jointly financed, planned and executed by a consortium of academic, public and industry partners (Davenport et al., 1998; vom Brocke & Lippe, 2015). In the section I subsection 2.1 has already been described the main characteristics of collaborative projects such as the heterogenous networks of partners with diversity of backgrounds and interest (Calamel et al., 2011; Malherbe, 2022), collective responsibilities (Calamel et al., 2011; vom Brocke & Lippe, 2015), intensive process of tacit knowledge integration (Faccin & Balestrin, 2018) or ambiguous and moving project goals (Gama et al., 2017). In this section, we provide a deeper conceptualization about the subject of analysis: collaborative research projects, a subtype of collaborative projects.

In most cases, collaborative research projects are initiated in response to calls from public funding agencies, which often serve as the primary investors in collaborative innovation efforts (González-Piñero et al., 2021; vom Brocke & Lippe, 2015). For instance, the latest H2020 European program has allocated almost 40 billion euros to fund over 7000 projects (Klessova et al., 2022). Examples of well-known public policies aimed at accelerating the technological transition from academia to society include Cooperative Research Centres (CRCs) in Australia (Garrett-Jones, Turpin, Burns, & Diment, 2005), French clusters (Calamel et al., 2011), university-industrial collaborations in Japan (Hemmert et al., 2014) and Portugal (Fernandes et al., 2021).

Publicly funded collaborative projects differ significantly from other interorganizational projects, making their management even more challenging (Fernandes et al., 2021). Decisions are collectively made within a heterogeneous network of partners with diverse backgrounds and expectations (Calamel et al., 2011). Partner expectations are often not openly communicated to the consortium due to hidden internal agendas and interests among some partners (vom Brocke & Lippe, 2015). Moreover, these projects are governed by contracts defined by the sponsoring organization, granting equal decision rights to all parties involved (vom Brocke & Lippe, 2015). This limits the authority, autonomy and execution power of the project managers (Calamel et al., 2011; Klessova et al., 2020). Additionally, these projects are required to adhere to rigid budget constraints, milestones, and consortium memberships (vom Brocke & Lippe, 2015). These issues further complicate stakeholder alignment and decision-making processes, and differentiate collaborative projects with other interorganizational projects governed by supplier-contractor relationships (vom Brocke & Lippe, 2015).

Publicly funded collaborative projects are initiated to tackle uncertain, complex, novel, and ambitious scientific or technological problems (König, Diehl, Tscherning, & Helming, 2013). These problems can be categorized according to the Technology Readiness Level (TRL) of the primary project activities, situating them either closer to basic research or industrial development (Chiesa & Frattini, 2007). The objectives in each case are distinct. While basic research aims to generate novel scientific knowledge outputs, development projects aim to create innovative outputs associated with more precise and tangible project results (Arranz & de Arroyabe, 2008). This research focuses on projects whose primary results are linked to novel scientific or technological outputs, commonly referred to as collaborative research projects (Davenport et al., 1998; vom Brocke & Lippe, 2015) or collaborative exploration projects (Solís-molina et al., 2020).

Collaborative research projects face complexities arising from conflicting requirements: the necessity to establish ambitious scientific/technological goals to meet the sponsor's expectations (a prerequisite for project approval), while simultaneously lacking a clear idea of the means to achieve them (Wied et al., 2020). The project plan serves as a 'hypothesis' for how success will be achieved and provides a baseline from which deviations can be observed (Wied et al., 2020). This results in a noticeable mismatch between traditional project management approaches, which are built on the assumption of high predictability in project outputs and further development of project plans (Geraldi et al., 2011), and the uncertain and unpredictable nature of research projects (Wied et al., 2020). This mismatch might explain also the high failure rate of collaborative research projects.

In this sense, this research focuses on collaborative research projects (vom Brocke & Lippe, 2015) due to their high failure rate, the inherent uncertain nature, and the limited applicability of traditional project management approaches. Specifically, the study will delve into the implications of the inherent uncertain environment of these projects, particularly their ability to overcome perturbations caused by unpredictable threats (Naderpajouh et al., 2020).

8.2 The uncertainty nature of collaborative projects. A resilience perspective.

Uncertainty management has been one of the most researched topics in the project management field, largely associated with risk management (P. Daniel & Daniel, 2018; Naderpajouh et al., 2020). The underlying assumption of traditional risk management approaches is the fact that managers are capable enough to estimate probabilities and consequences of unknown events (Naderpajouh et al., 2020; Rahi, 2019). However, in environments characterized by high uncertainty, the success of projects relies more on their capacity to navigate disruptions caused by unexpected events (Fey & Kock, 2022) rather than on accurate predictions of known potential events (Yang et al., 2022). In recent years, there is an increasing interest of the scientific community to shift the focus from mitigating known vulnerabilities (risk management) to overcoming unknown disruptions (Naderpajouh et al., 2020). In this context, the concept of resilience offers a deeper understanding of how teams can effectively overcome disturbances arising from "unknown unknowns," which are significant and inevitable in collaborative research projects (Wied et al., 2020). Resilience management, rather than being seen as supplementary, can be considered as a complement to risk management in the process of dealing with uncertainties (Rahi, 2019).

In the literature of project management, perturbations have been associated with the well-known concept of “unknown unknowns” (Wied et al., 2020). These are related to situations where neither performance variables, uncertain variables, nor the relationships between them are known in advance (Lempert, Popper, & Bankes, 2004). These situations can be either endogenous, such as a partner abandoning the project (White, 2005) or exogenous, such as supply chain disruption or the pandemic of COVID-19 (Naderpajouh et al., 2020) or market and technological uncertainty (Majchrzak et al., 2015).

Perturbations are not only originated by unpredicted events (shocks), but also by latent or chronic issues that are dramatically exacerbated in a conflict situation (stressors) (Helbing, 2013). For instance, different understandings about the project goal among partners can be a latent issue that suddenly emerges as a conflict when the team needs to reach agreements whose implications might affect negatively some of their interests (Ness, 2009). Adopting a systemic approach (Figure 5) a project can

be viewed as a dynamic system that experiences a continuous cycle of stability and instability, effectively responding (or not) to perturbations (Majchrzak et al., 2015).

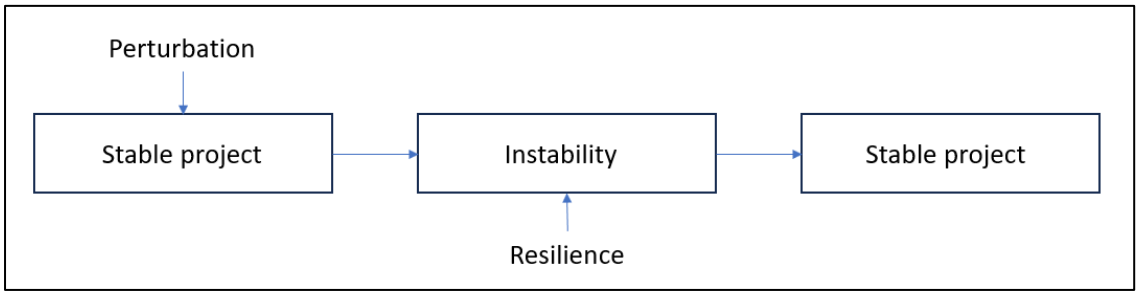


Figure 5: Resilience perspective to overcome instability

The concept of resilience has its roots in engineering, biological and ecological studies (Holling, 2013; Smit & Wandel, 2006). In most cases, resilience is treated as a capability, "*a dynamic process or system, being able to adapt to disruptions or perturbations*" (Masten, 2014). This approach suits a variety of phenomena from microorganisms to global change and natural disasters. In the realm of organizational science, resilience has been garnering increased attention due to the growing complexity of organizations and the uncertainties in their environments. In the project management field, this topic has attracted increasing attention, particularly in the last five years, with some special issues featuring in top journals. As a result, various definitions of the concept now exist.

For instance, according to Bhamra R. et *al.* (2011), organizational resilience is related to "*the response of the organization to threats and disruptive events as well as the ability to restore function*". On the other hand, according to Naderpajouh et al. (2020) project resilience can be understood as "*the capacity to organize under a variety of scenarios, including disruptions in the form of shocks or stressors*". Rather than delving into intricate conceptualizations of resilience, this research adopts a more generic version, considering resilience "*as the ability to respond and adapt to perturbations, ultimately restoring the system's stability"* (Bhamra, Dani, & Burnard, 2011).

Following this perspective, a resilient project is one that can return to stability and continue with the project's development after facing perturbation.

8.3 Equivocality and governance during perturbations.

Interorganizational collaborations are exceedingly unstable, but instability might produce either successful outcomes or failure projects as well (Majchrzak et al., 2015). Unpredictable situations introduce instability, where situations of equivocality tend to be exacerbated and trigger a process of change or adaptation. According to Majchrzak et al. (2015), misunderstandings among partners, signal of equivocality, can initiate processes of change that are linked to either positive or negative

outcomes. These disparities among partners may either enhance collaborative capacity or result in project failure or diminished collaboration. Both types of results depend on the managerial strategies applied to manage it (Majchrzak et al., 2015).

This is aligned with the conceptualization of equivocality acting as a double-edged sword (Figure 6) in collaborative projects (Eriksson et al., 2016). The variety of perspectives emerges as a crucial factor to deal with, and two opposing implications are known (Eriksson et al., 2016):

> (1) equivocality acting as a driver for knowledge exploration activities (Dodgson, 1993; Marcandella & Guèye, 2018; Mu et al., 2021). The tensions are the trigger to develop a deeper understanding of the nature of the issue and its consequences, reframing the existent knowledge of each partner to find novel solutions for unexpected issues (Kleinsmann et al., 2010). The tensions produced by equivocality might foster knowledge exploration activities to improve value-cocreation, as it was the case of Browing (1995).
>
> (2) Equivocality, acting as a barrier for knowledge exploration and integration, restricting the team's capacity to reach agreements and intensify tensions among partners (Burström & Wilson, 2018; Ness, 2009). These misunderstandings compel the partners to safeguard their individual interests and prioritize individual goals over collective objectives (Leufkens & Noorderhaven, 2011; Malherbe, 2022). Consequently, negative performance implications arise, as reaching agreements necessitates significant time and resource´s investment (Daft & Lengel, 1986), as it was the case of Ness (2009).

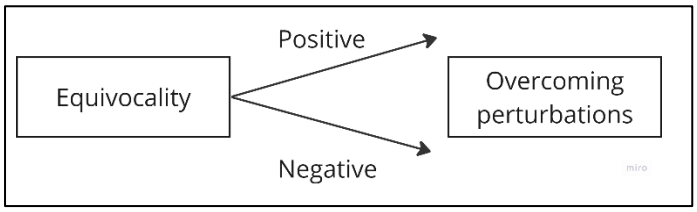


Figure 6: Double-edged sword implications of equivocality in the process of overcoming perturbations

In both cases, the implications of equivocality on the process of dealing with perturbations are moderated by the governance approaches taken to overcome them (Majchrzak et al., 2015). From a managerial perspective, governance approaches play a central role in the process of overcoming perturbations and managing the double implications of equivocality on the project results during perturbations (Eriksson et al., 2016; Morandi, 2013).

As explained in chapter 2.6, governance in collaborative projects has been primarily conceptualized as a dichotomy between complementary effects (enabler/compensator) or substitution effects (either/or) between relational and formal governance. Benitez-Avila *et* al. (2017) found positive

effects of the complementarity role of governance approaches, acting as enable/compensator into project results. They suggest that a contractual agreement is a necessary condition to rule the partners behaviours, but it is not enough to assure partner implications, in which relational approaches translate contractual provisions into real partner´s contributions. When this relationship is found, better project results are associated with (Benítez-Ávila et al., 2018; Cao & Lumineau, 2015).

Disruptions demand for changes and adaptations in governance (Yang et al., 2022), otherwise, there is an escalating risk of failure in addressing unforeseen threats. In uncertain and complex environments, the complementarity effect between formal and relational governance might be associated with better results in the process of overcoming disruptions (Yang et al., 2022) compared with the substitution effect. This is because unforeseen threats necessitate the adaptation of contractual agreements and an increase in relational actions to comprehend and address unknown situations, as it shown in Figure 7.

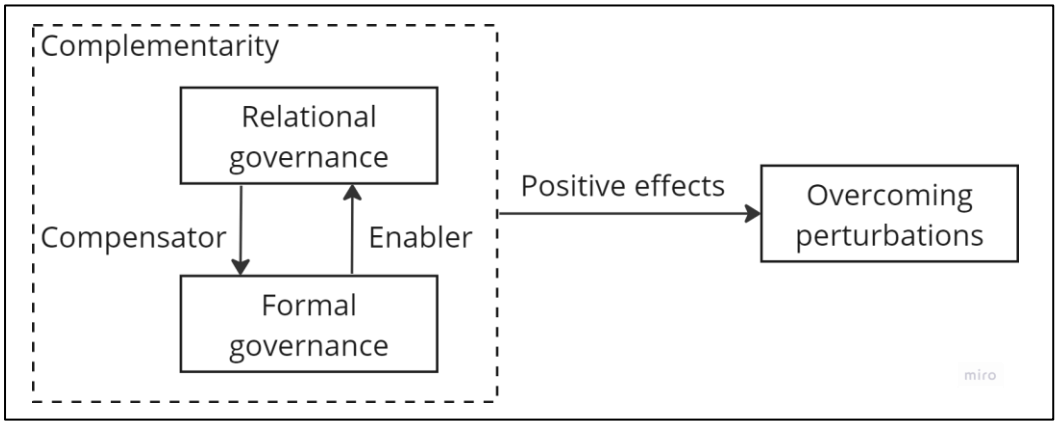


Figure 7: Implication of governance in the process of overcoming perturbations

Additionally, governance approaches not only affect the process of overcoming perturbations, but also, they moderate the positive or negative implications of equivocality (Figure 8). On the one hand, formal and relational governance might be associated with positive implications in dealing with equivocality during perturbations:

- contractual agreements contribute to clarify roles and responsibilities to reduce the variety of potential interpretations (Yang et al., 2022).
- Relational approaches enable knowledge exchange and a deeper communication required to align different perspectives (Derakhshan et al., 2020; Sakka et al., 2016). These relational approaches might increase trust among partners and in uncertain situations, trust enables reducing conflicts and tensions between partners (Davenport et al., 1998; Leufkens & Noorderhaven, 2011).

On the other hand, formal and relational governance might be associated also with negative implications in dealing with equivocality during perturbations:

- in uncertain situations, contractual agreements might be also source of misunderstandings, as the partners conceive the unknown situation and its contractual implications in a different way (Morandi, 2013). Relying on what has been contractually agreed might limit the emergence of novel or innovative solutions, reducing flexibility and creativity required to solve unknown issues (Patel et al., 2018; Sicotte & Langley, 2000).
- Then, increasing communication through relational approaches might also be detrimental, as the tensions between partners might be exacerbated, following a negative loop made of arguments and counterarguments, increasing time and resources invested in communication but reducing the possibility of reaching common agreements (Knudsen & Srikanth, 2014; Ness, 2009).

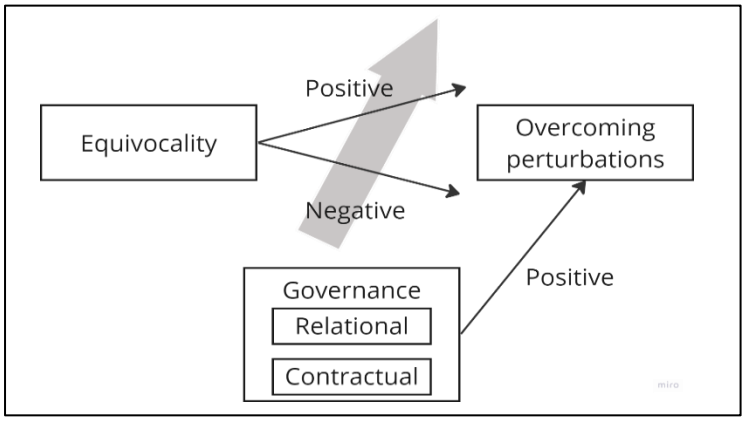


Figure 8: Moderating role of governance in the double implications of equivocality on the process of overcoming perturbations[3]

The relationship between equivocality and governance is far for being considered as made of lineal causality in complex situations (Majchrzak et al., 2015). Studying this relationship as made of lineal causality does not allow to capture the complex reality of overcoming perturbations. A change in one parameter leads to non-linear changes in the other and vice versa, being this relationship better explained by mutual loops rather than cause-effects analysis (Majchrzak et al., 2015). Managing equivocality requires adapting governance approaches to unexpected situations, but also, the latter might reduce or exacerbate the former. This research is not aimed to analyse where the relationship starts, contrarily, is aimed to understand the dynamic evolution of the mutual relationship between the constructs. Different governance approaches might affect both sides of the sword of equivocality

[3] Thick arrows in this research represent the moderating role played by one variable within the relationship among two or more others.

(Eriksson et al., 2016). Majchrzak et al. (2015) provided rigorous evidence of the different dynamics' loops between components in collaborative projects.

However, there is no research to date (as far as the author´s acknowledge) that explains how these two significant constructs might evolve in perturbations. It is fruitful to investigate different combinations between equivocality and governance modes that enable a project to overcome perturbations. Figure 9 represents a systemic approach about the interplay between equivocality and governance in the process of overcoming a perturbation.

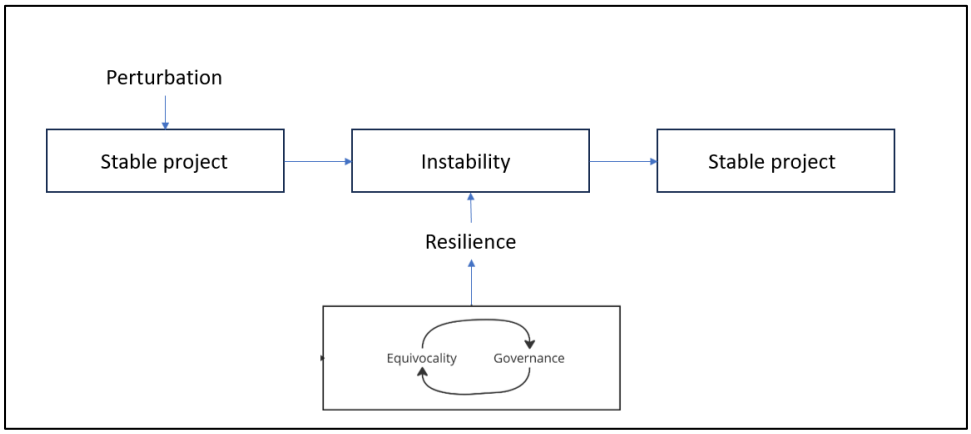


Figure 9: Systemic approach to capture the mutual interdependencies between equivocality and governance in the process of overcoming perturbations

8.4. The moderating role of organizational learning.

We claim that the learning capacity of the organizations also influences how they react and respond to perturbations (Morandi, 2013; Solís-Molina et al., 2021). In order to overcome perturbations, organizations need to adapt governance approaches and to manage the positive or negative implications of equivocality. We argue that both processes are moderated by the manner in which the organizations learn to overcome perturbations. In this sense, we focus our study in a broadly studied concept such as organizational learning, to understand different learning behaviours in response to change situations originated by perturbations.

Organizational learning is a concept broadly studied in the literature of organizations, and it is defined as the process through which organizations change or modify their rules, processes or knowledge, maintaining or improving their performance (Argyris & Schön, 1996). In the dynamic process of adapting governance approaches and managing equivocality, the role played by organizational learning is relevant to study, as this capability also enables a project to overcome perturbations.

According to Argyris and Schön (1976) (and their Organizational Learning approach), an organization might follow two types of learning processes, considered as single and double loop learning to react

to change situations. A single-loop learning represents a change in the surface of the methodologies and practices. Double-loop learning represents a change in the values that underpin the problem (McClory et al., 2017). At the project level, McClory et. al (2017) explain a step-by-step learning process when a project faces a trigger for change: starting with evaluation, decision making, reaction, learning and finally the action. Even though this approach explains the learning processes undertaken to face a change situation, each organization might follow different learning behaviours.

Single loop learning occurs when organizations make adjustments or fine-tune existing knowledge to address change situations without critically reviewing the underlying foundations of that knowledge (Argyris, 1976). Contrarily, if the organization challenges and reconsiders the underlying assumptions about a concept, problem or procedure, it is about double-loop learning, a deeper and higher-level learning process (Davenport et al., 1996; McClory et al., 2017). In a change situation, adaptive learning (single loop) means that the project adjusts its actions to return quickly to the system stability and there are no deeper changes in the project objectives, assumptions and strategy (P. Daniel & Daniel, 2018). Following a generative behaviour (double loop), the organizations modify the established processes and parameters to ensure the achievement of higher-level goals of both at the project and organisational level (Dodgson, 1993; McClory et al., 2017)

During a perturbation, different learning behaviours might be associated with different adaptation processes. Following an adaptive pattern, the teams involved may strictly limit discussions related to equivocality situations to topics such as time, cost, and scope (outputs), which may come at the expense of valuable outcomes, and focussed on exploiting the existent knowledge of each partner (Malherbe, 2022). In generative learning patterns, the tensions led by equivocality might be the trigger for expansive learning (Browning, Beyer, & Shetler, 1995; Dodgson, 1993), challenging the underlying assumptions of the problem and the governance methods applied to manage it (Marcandella & Guèye, 2018). The partners might invest time and resources on discussing their beliefs, looking for a mutual understanding that enables them to propose overreaching solutions that provide more value to stakeholders, focussing on outcomes rather than outputs (Malherbe, 2022). A generative learning behaviour might enable the teams to stimulate the diversity of perspectives (equivocality) to propose innovative solutions for unknown issues, focussing on knowledge exploration. An adapt learning behaviour might enable the team to quickly mitigate the negative implications of equivocality through superficial governance changes. Figure 10 summarizes graphically the role played by organizational learning in the process of overcoming perturbations.

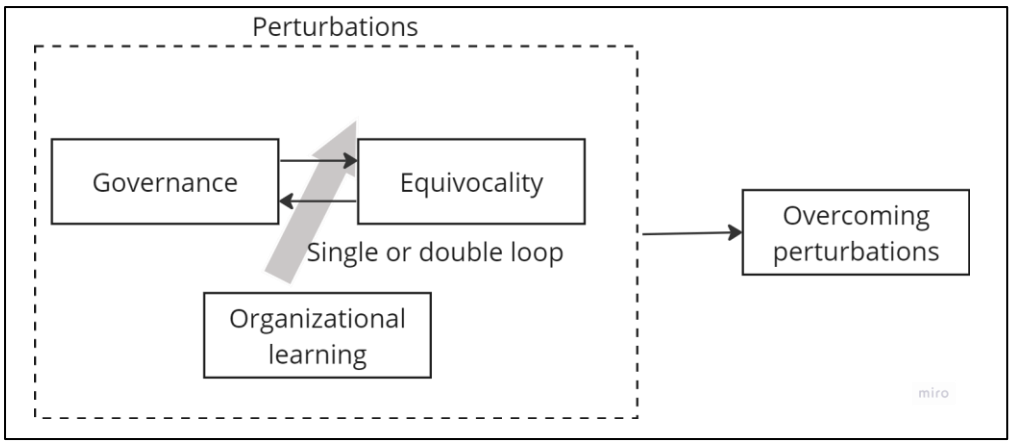


Figure 10: Moderating role played by organizational learning in the process of overcoming perturbations

8.5 Complex systems perspectives to deal with perturbations

Comprehending the causes of disturbances and formulating strategies to mitigate perturbations create a context highly subject to equivocality, given the diverse array of backgrounds and interests that coexist in collaborative projects. In this sense, managing equivocality becomes relevant during perturbations. According to the literature review, equivocality might lead to positive or negative project implications, either triggering or hindering knowledge exploration processes (Eriksson et al., 2016). Both types of implications are conditioned to the governance adaptation taken to overcome perturbations (Majchrzak et al., 2015). Changes in governance are required to react and adapt to disruptions. Additionally, a change in the governance of the project might produce, reduce or exacerbate equivocality among partners. During times of instability, a change in one of them produces non-lineal effects in the other and vice-versa, being this relationship better explained by feedback loops rather than lineal causality.

Perturbations clearly affect the stability of the project and force the organizations to propose contingency actions and trigger a process of change. Change management implies and requires learning processes (Davenport et al., 1996). The learning processes applied by the organizations involved in the process of overcoming perturbations clearly affect the result obtained after the perturbations. In this sense, we hypothesize that these learning behaviours affect how the project overcomes perturbations and also, the relationship between equivocality and governance. The partners' ability to overcome situations of equivocality through governance approaches depends on their learning capability (Eriksson et al., 2016). Drawing from literature, generative or adaptive learning has been identified as two different learning behaviours that affect how the organizations overcome change situations (Argyris & Schön, 1996). Analysing the role played by organizational learning as a moderator of these relationships might also improve the understanding about how the organizations overcome perturbations.

A research framework is proposed to capture the complex reality of overcoming perturbations in collaborative projects. The aim is to increase the understanding of how governance, equivocality and organizational learning relate to each other during perturbations and how the evolution of these interdependencies might explain how a project might overcome perturbations (Figure 11). As it is summarized Table 4 each one of them affects and is affected by the behaviour of the others, in a dynamic and evolving process of mutual causality.

The proposed framework aligns with Majchrzak et al (2015), as they have viewed collaborative projects as unstable systems. In such systems, instability stemming from similar causes can yield entirely different outcomes—either successful results or project failure. These outcomes are primarily linked to how the components dynamically evolve during periods of instability rather than the isolated effects of each component on the results. For that aim, the complexity theory is proposed as a research framework to capture holistically how a project is able to overcome perturbations, based on the interrelationships between the three constructs.

Mutual causality and non-linearity	Explanation	References
Equivocality <--> governance	The implementation and adaptation of governance approaches (either relational or contractual) might contribute to increase or mitigate equivocality levels.	Eriksson et al., (2016). Derakhshan et al., (2020). Morandi (2013) Yang et al (2022) Knudsen & Srikanth (2014) Patel et al., (2018)
	Equivocality situations might force also governance´s adaptations among partners.	Burström & Wilson (2018). Brun (2016b).
Equivocality <--> organizational learning	Equivocality might be the driver for deeper and higher-level learning processes.	Marcandella & Guèye (2018)
	Different learning behaviours influence the manner how a team manages equivocality.	Burström & Wilson (2018). Eriksson et al., (2016).
Governance <--> organizational learning	Adapting governance approaches between partners fosters a learning process.	Davenport et al. (1999)
	Different learning behaviours influence the manner how a team adapts governance approaches to different project conditions.	McClory et al. (2017) Solís-Molina M. et al (2022) Gulati et al. (2012) Argyris and Schön (1976).

Table 4: Mutual, dynamic and non-lineal interdependencies between equivocality, governance and organizational learning during perturbations

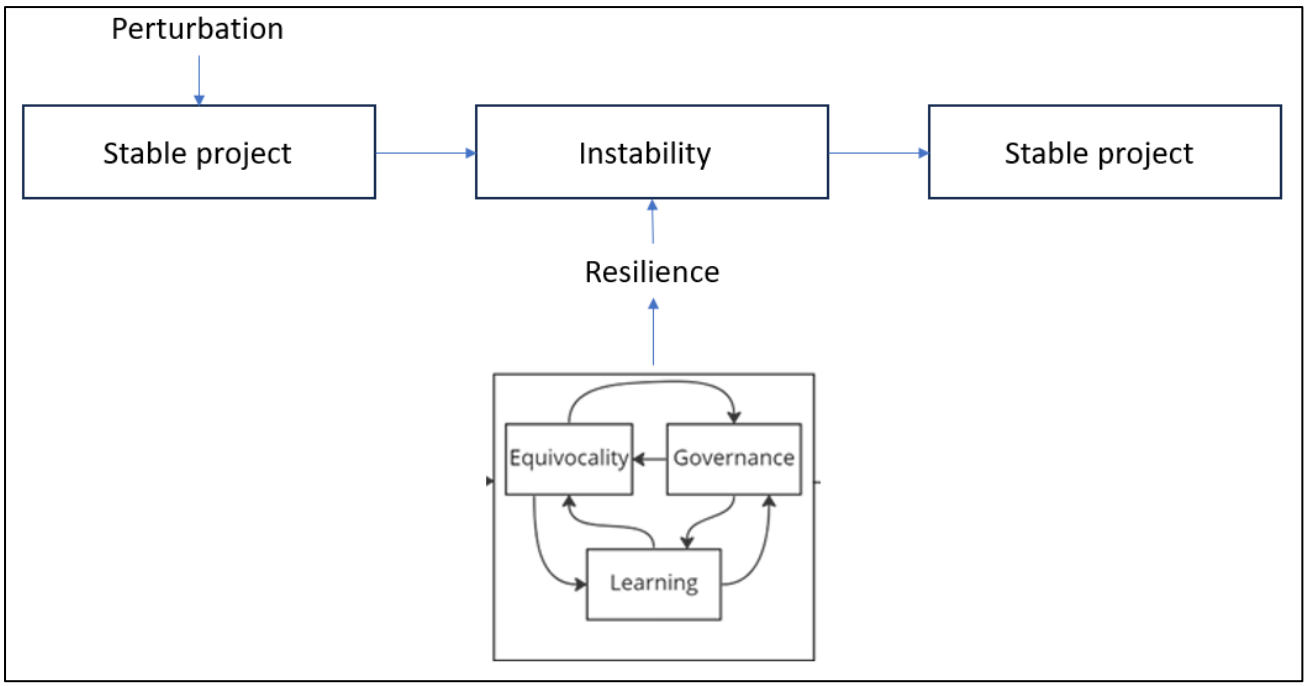


Figure 11: Interplay between equivocality, governance and organizational learning as a resilience perspective

9. Research framework: Complexity theory.

9.1 Research framework justification.

9.1.1 Introduction.

Daft and Lewin (1990) suggested that it is inappropriate for organizational studies to settle down prematurely into Newtonian or deterministic styles, because organizations are extremely complex, whose behaviour is hard to predict (Houchin & Maclean, 2005; Stewart & Cohen, 1994). In the project management field, deterministic approaches characterized by reductionistic lens, have been largely applied as a research framework to capture the nature of projects, mainly at the operative level (Crawford, Pollack, & England, 2006; Padalkar & Gopinath, 2016; Pinto, 2014). However, in recent years, a new stream of project management scholars has started to apply non-deterministic approaches to understand the complex social phenomenon of projects, based on concepts of emergence, self-organization and nonlinearity (Cooke-davies et al., 2009; E. Daniel & Daniel, 2019). This research is aligned with this call by considering collaborative projects as a complex social phenomenon (Arranz & de Arroyabe, 2008), and by applying complexity theory to capture holistically the mutual evolution of the three components: equivocality, governance and organizational learning during a perturbation.

9.1.2 Complexity theory definitions.

One of the first definitions of "complexity" in organizational science, developed by Simon (1969) argues that complexity occur when "a large number of parts interact in a non-simple way". In complex systems, the change in one or two parameters can drastically change the behaviour of the whole system (non-linearity in cause-effects relationships), and the whole can be very different from the sum of the parts (Anderson, 1999; Holland, 2006).

Tsoukas (1998, p293) justified the emergence of a new research stream in social science as "*If nature turns out to be much less deterministic than we hitherto thought… then perhaps our hitherto mechanistic approach to understanding the messiness we normally associate with the social world may need revising*". On the one hand, well-established sciences based on deterministic paradigms, following Newtonian approaches, show complex effects can be understood from simple laws, following replicable cause-effects models (Heylighen, Cilliers, & Gershenson, 2006). On the other hand, non-deterministic approaches such chaos theory demonstrates that simple laws can have complicated and unpredictable consequences; or complexity theory that describes how complex causes can produce simple effects in non-linear ways (Anderson, 1999; Stewart & Cohen, 1994). In complex scenarios, simplifying the phenomenon into boxes with one-directional interactions and assuming static relationships among the components can lead to incomplete models of reality

(Stewart & Cohen, 1994). Maruyama (1963) proposed that the relationships between concepts do not solely adhere to cause-and-effect patterns. Instead, he proposed that some phenomenon can be better understood as mutual dependencies between their components, occurring either simultaneously or in an alternating manner, transitioning from linear relationships to interconnected circles (Majchrzak et al., 2015; Maruyama, 1963).

9.1.3 Complexity theory justification.

When it comes to unique events such as innovations, the managers are not able to predict the expected outcome based on the interactions of the inputs, because forecasting becomes virtually impossible (P. Daniel & Daniel, 2018). In exploratory projects, the project plan represents a hypothesis of the final product, where there is no clarity about the means and processes to reach it (Wied et al., 2020). The unclear and moving goals (Gama et al., 2017) and the low capacity for managers to predict the final product (Wied et al., 2020) make the collaborative research project a complex phenomenon rather than a complicated task (Geraldi et al., 2011). That is because the product emerges as a result of dynamic and emergent interactions among partners, rather than being entirely pre-planned upfront (Williams, 2005).

More holistic approaches that capture the dynamic and emergent interactions of the system´s components, focussing on self-organization and the principle of emergence are required to analyse such complex social phenomena leaving behind the already theorized deterministic approaches (Cooke-davies et al., 2009; Williams, 2005). Applying non-deterministic approaches enable us to have a more comprehensive picture of complex interrelationship between constructs during perturbations. The non-deterministic paradigm calls for greater focus on non-linearity, instability and emergence (Cooke-davies et al., 2009; E. Daniel & Daniel, 2019) that are the core features of collaborative research projects.

As it was found in the literature, equivocality situations might exacerbate tensions between partners (Burström & Wilson, 2018) and these might produce either positive or negative implications on project results, according to the governance approaches taken to overcome them (Browning et al., 1995; Ness, 2009). However, changes in governance approaches might also reduce or exacerbate equivocality situations, generating a counter reacting effect (Du et al., 2014; Eriksson et al., 2016). Additionally, we claim that these mutual, dynamic and evolutive relationship is moderated by the learning capability of the team to overcome perturbations (Desai, 2010). The learning behaviour directly affects how the relationship between equivocality and governance evolves (Marcandella & Guèye, 2018) and the results of the process of overcoming perturbations. A change in one parameter produce changes in the former and vice versa. In this sense, these relationships might be better

explained by circular loops rather than linear causality (Majchrzak et al., 2015). Based on the non-linearity in the relationships, characterized by mutual causality, we justify why non-deterministic approaches are suitable as a research framework to capture the process of overcoming perturbations.

Applying complexity theory as a framework to analyse the dynamics of collaborative research projects is suitable for our research purposes. Firstly, employing a systems theory approach can help us understand the evolving dynamics that enable a project to overcome perturbations resulting from interactions between equivocality, governance, and organizational learning. Systems theory focuses on the arrangement of relationships between the parts, which connected them into a whole that is independent of the concrete substance of their elements (Arranz & de Arroyabe, 2008). Traditionally, most of the research in project management relied on static analysis of specific situations, reducing the problem to a set of variables with linear relationships by applying deterministic approaches (Padalkar & Gopinath, 2016). However, this research aims to break away from this conventional practice and embrace non-deterministic approaches to capture the global evolution of the project as a complex system during perturbations.

Secondly, viewing the process of overcoming a perturbation as a complex system, broken down into subsystems with nonlinear relationships might offer a holistic perspective on various system configurations, each exhibiting different learning behaviours (Chiva et al., 2010; Desai, 2010). The existing literature tends to overlook mutual and nonlinear causalities among constructs, which are prevalent in the context of innovation.

Thirdly, project management scholars promoted the idea that project phenomena would benefit from adapting complexity theory perspective and the concepts of emergence and nonlinearity (E. Daniel & Daniel, 2019; Majchrzak et al., 2015). This research has followed this claim by applying complexity theory, as it helps to capture non-lineal relationships between components.

9.2. Overcoming perturbations as a complex system approach.

Within the realm of complexity theory, various theories and models exist, including chaos theory, wholeness theory, complex systems, among others (Chiva et al., 2010). Our approach is to consider the process of overcoming perturbation as a complex system. The foundations of complex systems can be traced back to the seminal work of Simon (1966). Complex systems are different from systems that are merely complicated (Desai, 2010). If a system can be described in terms of its individual constituents and their lineal relationships (even if there are a huge number of constituents), it is a merely complicated system. If the interactions among the constituents of the system are of such a nature that the system as a whole cannot be fully understood simply by analysing its components, it is complex system (Arranz & de Arroyabe, 2008; E. Daniel & Daniel, 2019; Desai, 2010). The concept

of complex systems has its roots in to physical, biological, or social systems (Simon, 1996). In simpler terms, a complex system consists of heterogeneous elements (components) that interact in non-linear ways and the whole system is no longer the sum of its components (Simon, 1996). The behaviour of any of its components is affected by the behaviour of the other ones and the implications of the environment (Chiva et al., 2010). Therefore, the whole system represents the results of the evolution of the dynamic and non-lineal relationships of its components.

Anderson (1999) made significant progress by proposing the notion of complex systems at the organizational level, that are characterized by:

- Self-organizing networks: System´s components are interconnected by feedback loops (E. Daniel & Daniel, 2019). No individual actor singularly determines the collective behaviour of all components; rather, the behaviour of each component is influenced by the behaviours of others.

  At the level of collaborative projects, and their network of partners, this is even more relevant because the decision-making process is shared collectively among partners (Klessova et al., 2022). No partner has the formal authority to impose deadlines, objectives and specific requirements, as it is in the case of contractual relationships ruled by customer-supplier´s agreements (Calamel et al., 2011). In this sense, the members of the project should find the way to organize themselves to address the different project´s needs.
- Coevolution to the edge of chaos: system´s components coevolve with each other (E. Daniel & Daniel, 2019). The equilibrium that results from these co-evolutions is dynamic; small changes in behaviour at a given time produce small, medium or large changes in the outcomes at the next point in time t + 1. To some point, the evolution of the relationship between components might reach the edge of chaos, or situation of limited stability entailed by any unstable, different or shocking situation or decision (Anderson, 1999). At the edge of chaos, the system might adapt or transcend to return to system´s stability (Gell-Mann, 1994).

  In the case of collaborative projects, perturbations, in the form of shock or stressors (Naderpajouh et al., 2020) might also bring the components of the system to the edge of chaos, or temporal instability, demanding for changing and learning to recover system´s stability.
- Recombination and system evolution: The system evolves over time through the entries, exits or transformation of system components (E. Daniel & Daniel, 2019). The components or agents of the systems are formed by recombining elements that could previously be successful. System´s recombination enables its evolution and continuity, adapting or transcending its initial state (Chiva et al., 2010).

Collaborative projects have been considered as complex systems, for instance by Arranz N. and de Arroyabe J.C.F (2008). In their research, the interdependencies between the governance of the project, its network structure and its technological development constituted a complex system. Their assumptions reside on first, considering the mutual and interdepend nature of relationships between the subsystems. Second, that the causal relationship between input variables and output variables have a nonlinear nature (Arranz & de Arroyabe, 2008). The inherent nonlinearity of their relationships makes it challenging to foresee the technological outcomes, as they will emerge from dynamic and interdependent connections between the network structure, the technological needs and the governance of the project.

In essence, a complex system consists of heterogeneous elements (components) that interact in non-linear ways and the whole system is no longer the sum of its components (Simon, 1996). Their relationships are characterized by self-organization and their evolution might bring them to the edge of chaos (temporal instability) (Anderson, 1999). At the edge of chaos, the system is very complex, alternating between stability and chaos (Gell-Mann, 1994). In this unstable situation, learning occurs, and this brings the system to return to stability or to a permanent chaos (Chiva et al., 2010). However, different typologies of learning might occur, characterized by generative or adaptive learning (Senge, 1990), leading the system to self-transcendence or self-organization, respectively to return to stability (Chiva et al., 2014).

Based on the interdependencies and interactions suggested by the existing literature, we posit that mutual or circular causality might explain the relationship between equivocality, governance and organizational learning during perturbations. In our research, we consider that the three concepts constitute a complex system, as they are made up of heterogeneous elements which seem to interrelate with one another and with their surroundings. These concepts or subsystem appear to be partially connected to one another, so the behaviour of any one of them is affected by the behaviour of the other two.

The relationships between partners follow the principle of *self-organization*, as the decisions are shared collectively, demanding partners for self-organizing to tackle unforeseen issues (Klessova et al., 2022). Increasing levels of equivocality demands for changes in the governance, starting a feedback loop of mutual reactions, either reducing or increasing equivocality (Majchrzak et al., 2015). To some point, the system might reach the *edge of chaos* (originated by the evolution of the components or by an external factor/ decision), a situation of limited instability between forces that demands the project to change or adapt to recover stability (Gell-Mann, 1994). Edge of chaos is regarded as a phase of change. These changes trigger learning processes, characterized by either adaptability or

transcendence (Chiva et al., 2010). A complex system is able to adapt or transcend at the edge of chaos, leading to system *recombination and evolution*, modifying its properties and characteristics to fit the environmental needs (Simon, 1996).

However, not all the complex systems are either complex adaptive or generative systems. Agency – the ability to intervene meaningfully in the course of events (Giddens, 1984)-, is a key characteristic of adaptive / generative systems that differentiate them to merely complex system. Agents are entities that populate a complex system and partake in the process of spontaneous change in such a system; these agents possess schema, and their behaviors are based on a set of non-linear rules (Desai, 2010). Goals and behaviors of agents are likely to conflict, these conflicts or competitions lead agents to adapt to each other's behaviors, learn and evolve (Desai, 2010). However, such learning and evolution processes might follow different patterns either characterized by adaptability or transcendence (Chiva et al., 2010). In this sense, we claim the governance, equivocality and learning constitute a complex system during perturbations, but the learning behaviours might be characterized by adaptability, considering them as complex adaptive systems (Anderson, 1999), or by transcendence (Jantsch, 1980), considering them as complex generative systems (Chiva et al., 2010).

To sum up, in order to understand the evolution between equivocality – governance – learning during perturbations, we propose a framework based on the tenets of these two distinct types of complex systems: complex adaptive systems (Anderson, 1999; Desai, 2010; Gell-Mann, 1994) and complex generative systems (Chiva et al., 2010; Jantsch, 1980) broadly addressed in the literature of complexity theory. A complex system perspective enables the researcher to capture holistically the complex and non-lineal evolutions of interactions between components, being the outcome the result of interactions rather than the sum of the components (Majchrzak et al., 2015; Simon, 1996).

9.3 Research framework application. Complex adaptive and generative systems

Drawing from complexity theory, we consider three established concepts such as “self-organization vs self-transcendence” (Gell-Mann, 1994; Jantsch, 1980), “implicate vs explicate order” (Bohm, 1980) and “edge of chaos” (Anderson, 1999) to differentiate between complex adaptive and generative systems. Between the broad diversity of concepts and constructs existing the complexity theory, these three have been chosen due to their relevance in learning processes, following the approach taken by Chiva et al. (2010). Complex adaptive systems learn through “self-organizing” processes (Desai, 2010) and complex generative systems through “self-transcendence”, the representation of a new order (Bohm, 1980). In both cases the changes are catalysed at the edge of chaos or “bounded instability” (Gell-Mann, 1994).

Bohm (1980) described a concept called “implicate order” as a generative order related to the deep and inward order of reality. In order to approach this, it is required creative intelligence, which is an unconditioned act of perception (intuition) that must lie beyond any factors that can be included in any knowable law (Bohm, 1980). On the contrary, “explicate order” is the manifested world, which is represented through knowledge, schemas, rules, mental models, paradigms (Bohm, 1980). Generative learning behaviours are focussed on challenging implicate orders and after a reflection process, explicate orders are also modified based on a change in the former (Chiva et al., 2010). Adaptive learning behaviours move around explicate orders, as an improvement of the existent and accepted knowledge (Chiva et al., 2014).

On the one hand, “self-organization” is a process in which the internal organization of a system increases in complexity without being guided or managed by an outside source (Gell-Mann, 1994). No single agent completely determines the system’s behaviour, which is rather unpredictable and uncontrollable. Self-organization is a natural consequence of interactions between simple agents each one with their own schemata (Anderson, 1999). Pattern and regularity emerge without the intervention of a central controller. Self-organization is a natural consequence of interactions between simple agents (Anderson 1999).

On the other hand, Jantsch (1980) highlights that social systems are re-creative systems because they can create new reality; sociocultural human beings have the ability to create the conditions for their further evolution all by themselves. Creativity means the ability to create something new that seems desirable and helps to achieve defined goals. By anticipating the future and creating new reality, social systems might also transcend themselves (Chiva et al., 2010). “Self-transcendence”: the creative reaching out of a human system beyond its boundaries (Jantsch, 1980).

Complex systems are able to develop three types of behaviours: stable, unstable (chaotic) and limited instability, or tensions between various forces that place them at the “edge of chaos” (Chiva et al., 2010). When the components that form a system behave in a regular manner and the environment is also highly stable, the behaviour of the system is considered as stable. In this context, minimal learning, reaction and evolution is needed (Simon, 1996). In a state of permanent instability, there are high level of chaos between the components of the system and the environment is random. Although the algorithmic complexity is very high, minimal learning might occur in that state (Chiva et al., 2010). The "edge of chaos" refers to a moment of controlled instability, a phase change where multiple forces coexist, triggered by one or more components within the system (Gell-Mann, 1994). The system becomes highly complex and finds itself in a transitional phase between returning to stability or transitioning to chaos (Chiva et al., 2010). In this situation learning emerges, and self-organization

(Gell-Mann, 1994) or self-transcendence (Jantsch, 1980) might occur. A complex adaptive/ generative system can learn only when effective complexity is sizeable, that is, in conditions that are intermediate between chaos and stability, the edge of chaos (Gell-Mann, 1994).

9.3.1 Complex adaptive systems

Complex adaptive systems self-organize when they are at the edge of chaos (Gell-Mann, 1994). Adaptability is one of their main characteristics and it implies the system's capacity to adjust to changes in the environment without endangering its essential organization (Anderson, 1999). Adaptive learning is essential in these systems (Chiva et al., 2010), and it entails modifying the explicit order through a process of self-organization. It is also related to refinement and improvement of existing competences, technologies and paradigms without necessarily examining or challenging the underlying beliefs and assumptions of the problem (Chiva et al., 2010). Adaptive learning involves improvements of the explicate order through a process of self-organization (Chiva et al., 2014). Implicate orders are not necessarily challenged in this typology of systems (Bohm, 1980).

System characterization (according to Chiva et *al.* 2010): Complex adaptive systems can be characterized when individuals or groups follow logic or deductive reasoning, concentrate, discuss and focus on improving processes or knowledge (explicate order) (Chiva et al., 2010). Deductive reasoning starts with general principles or premises and uses them to figure out specific information or truths about each part of a whole. As these are evident and accepted truths, there is no need to question them, taking the implicate order for granted and improving explicit orders by logical reasoning. Improvement can be defined as the refinement of existing knowledge and competencies, without challenging the underlying assumptions of the problem. Concentration is a process of forcing the mind to narrow down to a point, avoiding seeing the whole picture. Discussion implies a dialectic conversation or the exchange of arguments and counterarguments, where there is no collective knowledge building. The aim of the dialectical method is to try to resolve the disagreement through rational discussion and, ultimately, the search for truth or objective reality to improve the explicate order.

9.3.2 Complex generative system.

Complex generative systems are related to self-transcendence, which implies a process driven by the agents towards the implicate order (Jantsch, 1980), where they self-transcend to develop a new order (Chiva et al., 2010). Self-transcendence is one of the key characteristics of generative systems, as it enables the creation of a new reality beyond the initial boundaries. The process of self-transcendence implies going beyond any explicit knowledge (explicate order), approaching the implicate order of the things (Bohm, 1980), being "creation" its main outcome (Jantsch, 1980). Generative learning is

essential to enable the system to transcend at the edge of chaos. Generative learning requires new ways of looking at the world, modifying the mental models and paradigms that form the reality (Senge, 1990). Generative learning is a self-transcendence process that might take place in individuals and groups within organizations.

System characterization (according to Chiva et *al.* 2010): Complex generative systems are characterized by intuition, attention, dialogue aimed to question any implicate order (Chiva et al., 2010). Intuition is defined as a process of coming to direct knowledge without reasoning or inferring, a process of knowing the truth without explanations, a required process to challenge the implicate order, an act of perception (Bohm, 1980). Attention is a state in which the mind is open, without a focus, so it implies trying to be aware of the whole picture rather than concentrating on the existent knowledge. Attention must be cultivated as it emerges in a safe environment when the team members feel secure of any punishment (Senge, 1990). Dialogue can be considered as the collective inquiry into the process, questioning the accepted knowledge and its underlying assumptions. In dialogue, nobody is trying to win; everybody wins if anybody wins (Bohm, 1980). Instead of discussing different perceptions (dialectic; to break apart; to win), people suspend them and explore the broad range of assumptions taken for granted. Inquiry consists of reconceptualizing the knowledge in a novel and generative way (Chiva et al., 2010)

The following Table 5 summarizes the characterization of each type of system, based on the work done by Chiva et al. (2010).

Learning type	Adaptive learning	Generative learning
Complex system	Complex adaptive system	Complex generative system
Process	Self-organization	Self-transcendence (holo-organization)
Order	Explicate order	Implicate order
Individual, self (I)	Logic deductive reasoning	Intuition
	Concentration	Attention
Group, social (We)	Discussion	Dialogue
Aim, task (It)	Improvement	Inquiry

Table 5: Complex generative and adaptive system´s characterization. Chiva et al. (2010)

In the empirical work of Chiva *et* al. (2014), the researchers applied the theoretical models drawn from the complexity theory into two case studies, using them to analyse the mutual interaction between internationalization, innovation and organizational learning. Similarly, to our research, organizational learning was the capability taken as enabler, leading the system either to self-transcendence or self-organization. These are two empirical evidences of complex adaptive or generative systems to approach a similar phenomenon.

Perturbations might lead the system to the edge of chaos, a state of limited stability (Naderpajouh et al., 2020). To overcome these challenges and continue progressing with outputs and delivering value, the actors involved must adapt and respond to the unknown threats. According to the complexity theory, in an unstable situation, systems may react by exhibiting self-organization or self-transcendence behaviours, each characterized by different learning processes (Chiva et al., 2010). The following section explains the theoretical framework applied to tackle our research problem.

9.4 Research framework model. Complex Adaptive and Generative systems during perturbations.

According to Simon (1996), a complex system is made of heterogeneous elements that interrelate to each other through non-lineal relationships and also, with their surroundings. Systemic perspectives focus on the interrelationships between the parts, which connect them into a whole. This determines a system, which is independent of the concrete substance of their elements. Systemic perspectives enable us to break down the dimensions of the problem into already simpler subsystems, that we can approach them from fields of studies already theorized (Simon, 1996). In this sense, we claim that during perturbations, equivocality, governance and organizational learning constitute a complex system with non-lineal relationships between them. We approach each construct from already theorized concepts, as it was developed in the literature review. Not all the systems evolve following the same patterns at the edge of chaos (Chiva et al., 2014). In this sense, we propose a preliminary framework derived from the literature review, considering conceptualizations of generative and adaptive behaviour of each construct (subsystem). This framework provides plausible explanations for various behaviours observed during the process of overcoming perturbations, based on the interactions among these constructs. It represents the researcher's endeavour to integrate two fields: collaborative projects (and their related constructs) and complexity theory (system behaviours). The description is organized based on the subsystem behaviours drawn from the literature of collaborative projects, and the overall system behaviour, based on the complexity theory.

9.3.1 Complex generative systems during perturbations.

At the edge of chaos, the system is very unstable with multiple forces coexisting. To react, the system might transcend to its initial state and recover stability, becoming a more robust and reliable system (Jantsch, 1980).

Subsystem´s behaviours.

Equivocality situations might act as a driver for knowledge exploration and expansive learning (Davenport et al., 1996; Marcandella & Guèye, 2018). Equivocality tolerance levels might remain variable according to the type of knowledge-creation activity because higher tolerance levels enable

creativity and flexibility required for knowledge exploration activities and innovation (Sætre & Brun, 2013). The team members engaged in addressing the perturbation may offer varied solutions stemming from diverse knowledge domains to address unforeseen risks. This creates a fertile environment where a variety of perspectives coexist. Within this context, knowledge from various domains can complement one another, resulting in a joint solution and shared learning outcomes (Bäck & Kohtamäki, 2016). Generative systems are characterized by attention and intuition. Enhancing the team members´ capacity to navigate higher levels of equivocality fosters openness to innovative solutions. These solutions emerge from the combination of diverse perspectives aimed at addressing unforeseen challenges—an exemplification of attention (Brun, 2016).

Regarding governance, complementarity between formal and relational characterizes generative behaviours. Formal governance enables relational exchanges, and the latter compensates for the limitations of the first one (Benítez-Ávila et al., 2018). This complementarity lies in its high adaptability, allowing a team to modulate formality and flexibility levels in response to various scenarios stemming from unknown situations (Cao & Lumineau, 2015; Chakkol et al., 2018). The perspective advocating for complementarity argues that either relational or formal governance "enables" the necessary conditions to support the other type (Huber et al., 2013). In addition to enabling mechanism, a "compensating" mechanism also plays a role in addressing the limitations of the other governance type (Cao & Lumineau, 2015). For instance, having clear definitions of roles and responsibilities enhances trust among partners, serving as an enabling factor (Davenport et al., 1998). Then, trust among partners can facilitate the adaptation of contracts to new and unforeseen situations, compensating for the limitations of the initial ones (Gulati & Nickerson, 2008). Complementarity between governance approaches is a characterization of a generative system.

Projects exhibiting generative behaviors primarily rely on double-loop learning for organizational learning (Argyris & Schön, 1996). Collaborative projects have the potential to encourage higher level learning, not only about technology and knowledge but also about management and business (Dodgson, 1993). Generative learning implies reflection, inquiry, learning and change; it is ideal but also rare (Davenport et al., 1996). In a generative learning, organizations challenge their underlying assumptions about the knowledge foundations of the project and also about the managerial strategies. It is a deeper and a higher-level learning process (Marcandella & Guèye, 2018). Generative learning empowers interorganizational teams to reframe the foundational knowledge of each team, fostering a shared understanding (Eriksson et al., 2016). This process aids in bridging knowledge gaps and effectively addressing unforeseen risks. The generative learning process is associated with double-loop learning (Argyris, 1976).

Overcoming perturbations following a generative behaviour.

There are certain behaviours that characterize how the overall system behaves following generative patterns in the process of overcoming perturbations. As it was described by Chiva et al. (2010), a generative system is characterized by attention, intuition, dialogue and inquiry. This section aims to provide explanations about how these concepts are adapted into our system configuration, characterizing when a system follows generative behaviours in reaction to perturbations.

The system's behaviours are characterized by attention, where partners are open-minded and willing to inquire, receive, and embrace diverse perspectives beyond their own knowledge domain (Brun, 2016). Intuition also characterizes this system as relying solely on previous knowledge can hinder the creation of new understandings of reality (Chiva et al., 2010). Knowledge exploration activities are more related to attention and intuition, and the result of this process might be associated with a novel output originated from the combination of diverse knowledge domains (Kleinsmann et al., 2010).

Partners invest their time and resources in knowledge creation activities, driven by the emergence of diverse perspectives (equivocality) and supported by a dialectic based on dialogue (Knudsen & Srikanth, 2014; Leufkens & Noorderhaven, 2011). Then, by adapting and combining governance approaches, both relational and formal, the team demonstrates a behaviour centred around dialogue. Through this process, the teams reach agreements that modify existing working methods, goals (either individual or global) and project strategies to meet unexpected issues (Yang et al., 2022)

In response to a perturbation, the project might transcend to its initial situation. Self-transcendence can be viewed as the process of combining governance modes to adapt to variable equivocality situations, aimed at expanding the knowledge base of teams to provide novel solutions for unexpected scenarios—a higher-level learning process (Marcandella & Guèye, 2018). After overcoming a perturbation, the system becomes more reliable, as the teams' knowledge foundations were challenged, managerial strategies were reframed, and a joint knowledge output is achieved through a deeper learning process (Jantsch, 1980). This result can be observed in an enhanced collaborative capacity among partners, whether it is an increase in intensity, quality, or the outcomes of collaboration (Leufkens & Noorderhaven, 2011; Ness, 2009). It can also manifest as a novel output resulting from the knowledge exploration process or joint outcomes developed collaboratively among partners (Bäck & Kohtamäki, 2016).

9.3.2 Complex adaptive systems during perturbations.

Subsystem´s behaviour.

Equivocality might act as a barrier for knowledge exploration and integration, restricting the team's capacity to reach agreements and intensifying tensions among partners (Burström & Wilson, 2018; Ness, 2009). During a perturbation, misunderstandings might compel the partners to safeguard their individual interests and prioritize personal goals over collective objectives (Leufkens & Noorderhaven, 2011; Malherbe, 2022; Ness, 2009). The tensions exacerbate their cognitive limitations as the partners might remain closer to their knowledge domain rather than exploring new perspectives (Burström & Wilson, 2018). In a conflictive situation they might tend to reduce misunderstandings based on what the formal agreements dictate, and these decisions usually tend to focus more on knowledge exploitation activities among partners (Solís-Molina et al., 2021). In this sense, equivocality hinders processes of knowledge exploration, being knowledge exploitation the preferred search strategy to tackle the unforeseen situation (Eriksson et al., 2016).

The governance in teams characterized by adaptive behaviours is mainly explained by the substitute effects between formal and relational approaches (Cao & Lumineau, 2015). Adaptive behaviour becomes evident when the team predominantly relies on one governance approach rather than a combination of both during perturbations. For example, adhering strictly to the initial goals defined in contracts during perturbations can limit the team's capacity to consider novel solutions that may fall outside the scope originally defined. Using the implications of contractual governance as the primary mechanism to address tensions among partners undermines the utilization of relational mechanisms and leads to increasing mistrust among them (Gulati et al., 2012). Adaptive behaviours in governance occur due to the tendency for faster and superficial adaptations of managerial strategies to tackle perturbations, with heavy reliance on what contractual agreements dictate (Solís-molina et al., 2020).

The organizational learning in teams characterized by adaptive behaviours is mainly based on single loops learnings (Argyris & Schön, 1996). When the organizations face a changing situation, the knowledge foundations of the teams and the managerial strategies are not challenged, rather these are adapted without modifying their core assumptions (Anderson, 1999). Adaptive learning is faster as it is the result of knowledge exploitation (rather than exploration) of partners (Solís-Molina et al., 2021). The knowledge created is made of small and superficial improvements of the existing knowledge of each partner, based on previous experience (Chiva et al., 2014). There is not a collective process of reframing the knowledge assumptions of the partners to create novel solutions. The partners' focus is mainly on exploitation activities (Nisula et al., 2022).

<u>Overcoming perturbations following an adaptive behaviour.</u>

There are certain behaviours that characterize how the overall system behaves following adaptive patterns in the process of overcoming perturbations. As it was described in Chiva et al. (2010), an adaptive system is characterized by discussion, improvement and concentration.

In an adaptive system, when a team faces a change situation, individual objectives often take precedence over common objectives (Malherbe, 2022). Partners tend to focus on finding solutions that align closely with their interests and areas of expertise, aiming to utilize fewer resources and accomplish the task in less time (Leufkens & Noorderhaven, 2011). This occurs because each partner seeks to maximize their individual benefit from the project (Leufkens & Noorderhaven, 2011). Consequently, knowledge exploitation activities tend to be more prevalent than knowledge exploration activities (Solís-Molina et al., 2021). As a result, the level of change is more closely associated with an improvement in the existing knowledge rather than engaging in inquiry or exploration of new knowledge (Arranz & de Arroyabe, 2008). In this sense, improvement characterizes a system focused on adapting existing knowledge and resources to the unknown situation.

The partners focus on concentration when they face a change situation, avoiding seeing the whole picture, forcing the overall consortium to make decisions closer to their current knowledge domains (Malherbe, 2022). As the individual interests tends to prevail to the common interest, the dialectic is mainly based on arguments and counterarguments aimed to keep closer to each of the partner´s interests (Knudsen & Srikanth, 2014). This is associated with discussion as the dialectical exchange.

Self-organization is characterized as the capacity of the team to adapt to an unknown scenario and return to stability (Gell-Mann, 1994). The partners tend to focus on exploiting the existing resources and knowledge to find solutions that enable quick implementation rather than exploring potential novel alternatives (Brun, 2016). In this sense, equivocality might restrain resources as individual interests coexist with common interests (Leufkens & Noorderhaven, 2011). Contractual agreements enable better knowledge exploitation and safeguard the partner's interest (Solís-molina et al., 2020). Adapting governance approaches (mainly through contractual implications) to reduce the misunderstandings requires learning, mainly superficial ones to enable the team to continue collaborating after the perturbation (Sætre & Brun, 2013).

When a project responds to disruptions by following adaptive patterns, the outcomes of this process may be linked to minimal alterations in the project/product scope, as the search strategy is more effectively executed through knowledge exploitation activities (Solís-molina et al., 2020). In a conflicting scenario, if the chosen knowledge search strategy focusses towards exploiting existing knowledge and superficial learning, it is reasonable to assume that the parties involved may not

necessarily enhance their collaborative capacity (Klessova et al., 2022), and the results are more closely associated with incremental outputs (Arranz & de Arroyabe, 2008; Chiva et al., 2014).

9.3.3 Research framework implementation.

To sum up, the following table Table 6 and Figure 12 summarize the adaptation of the complexity theory, specifically complex adaptive or generative system, to improve the understanding of how a collaborative team might overcome a perturbation. When a system faces a perturbation, this can react follows self-organization (Anderson, 1999) or self-transcendence (Jantsch, 1980) to return to stability. We propose a characterization of each one of the behaviours according to the literature review developed in each one of the constructs. This framework proposal explains different system´s configuration according to different reactions to perturbations, making evident there is not a unique manner to be resilient.

Further empirical study is required to validate the theoretical assumptions and to increase the understanding about how the constructs relate to each other dynamically in order to explain different resilient behaviours.

Subsystem	Adaptive	Generative
Equivocality	Barrier to reach mutual understanding and knowledge exploration (Frishammar et al., 2011)	Driver for expansive, deeper learning and knowledge exploration (Marcandella & Guèye, 2018)
Governance	Relational and formal governance acting as supplements, either /or (Granovetter, 1973)	Relational and formal governance acting as complements: enabler/compensator (Benítez-Ávila et al., 2018)
Organizational learning	Single-loop learning (Argyris, 1976; McClory et al., 2017)	Double loop learning (Argyris, 1976; McClory et al., 2017)
Subsystem characterization	Self-organization Concentration Improvement Discussion	Self-transcendence Attention Inquiry Dialogue

Table 6: Research framework proposal, based on generative and adaptive component´s behaviours

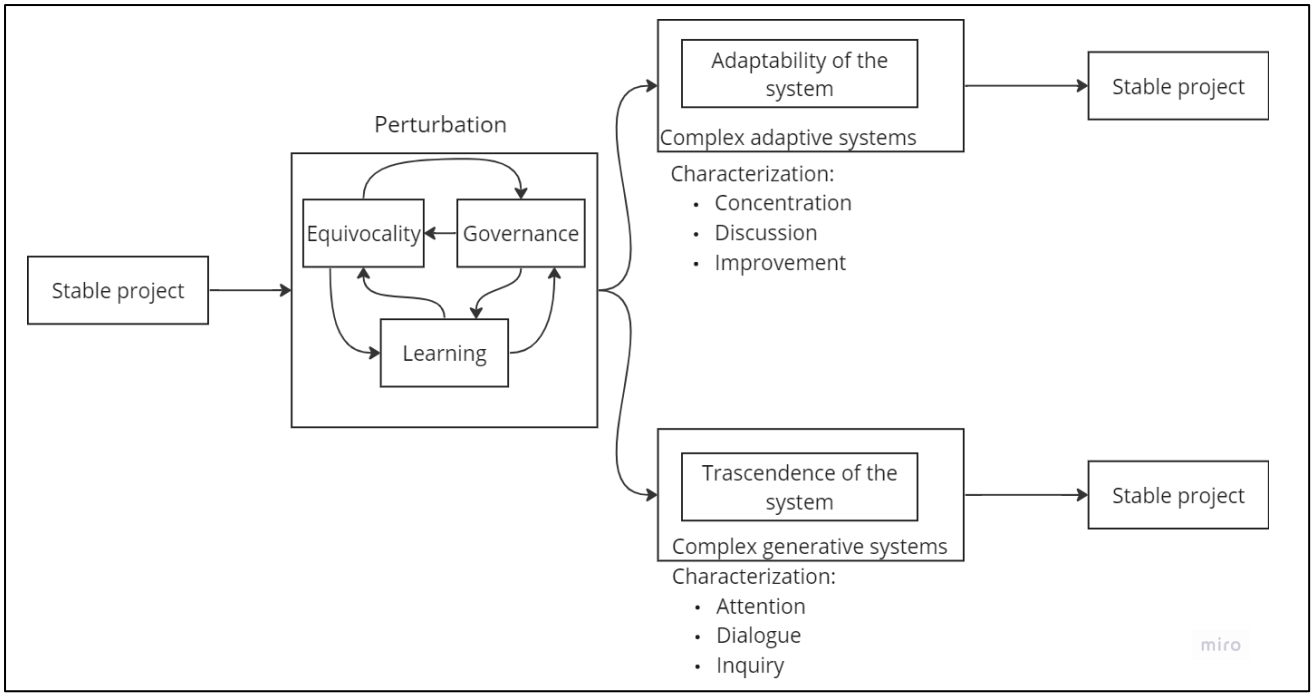


Figure 12: Research framework proposal

10. Methodology.

10.1 Introduction.

Qualitative approaches are suitable research methods to answer questions such as *how/what/why is it occurring?* (Langley & Abdallah, 2011). This research is made of a cross case analysis, based on a single case, a successful collaborative project, where two instances of perturbations and their related reactions are analyzed. The unit of analysis is the perturbation itself and the corresponding reaction that allowed the project to successfully overcome it. Cross-case analysis is applied to compare two different reactions to similar unknowns' perturbations. The project is called LOCUTIOS, where different (and legally independent) organizations (research centers) collaborated during a limited period (2013-2016) to develop remarkable progress in the field of human-voice simulation. Abductive approach is applied as a reasoning logic, as the research focusses on explaining how a successful project was able to overcome two perturbations. Abductive reasoning conducts a mutual engagement with empirical data and extant theoretical understanding (Sætre & Van de Ven, 2021). Abductive research aims to find plausible explanations and an improved understanding of a phenomenon (anomaly), based on the combination of contextual empirical data with already theorized frameworks (Thompson, 2022).

10.2 Case study justification.

The case study is a research strategy that aims to understand the dynamics within specific settings (Eisenhardt, 1989). Case studies can involve single or multiple cases, as well as various levels of analysis (Yin, 1994). Yin (1984) proposes three logical approaches for selecting sites in holistic case studies: choosing "critical" cases to test a specific theory, opting for "extreme" cases that involve exceptional circumstances, or selecting "revelatory" cases that offer high potential for developing new insight into an understudied phenomenon.

In this research, we follow abductive reasoning, to explore how collaborative projects overcome perturbations. While much of the existing research in project management focuses on risk management to handle uncertainty, collaborative projects are more susceptible to unknown unknowns, and their success relies on their ability to react and overcome these challenges (Yang et al., 2022). Nonetheless, this aspect remains relatively unexplored and calls for empirical investigation (Naderpajouh et al., 2020). As such, this research is deemed a "revelatory" case with substantial potential to offer novel insights in the field of collaborative projects.

10.3 Epistemological assumptions.

The case study is one of the most frequently used qualitative methodologies in management research (Langley & Abdallah, 2011). However, there is no consensus among methodologists regarding the

definition of a case study, its epistemological commitments, strategies for data collection and analysis, and how to derive theory from empirical findings (Yazan & De Vasconcelos, 2016). The reason for this lack of agreement is that a case study is a versatile tool that enables researchers to pursue various aims, such as providing descriptions, testing existing theories, or generating new ones (Eisenhardt, 1989). Qualitative methods, particularly the case study, are linked to different epistemological assumptions that influence the way data is collected, interpreted, and how theory is developed (Langley & Abdallah, 2011). Therefore, it is important to broadly describe the two main research approaches derived from two research paradigms: positivism and constructivism (Langley & Abdallah, 2011; Yazan & De Vasconcelos, 2016).

The *positivism approach* is drawn from the well-known works of Eisenhardt (1989) and Yin (1984). According to Yin (2004) case study research is supposed to maximize four conditions related to design quality: "*construct validity, internal validity, external validity, and reliability*". Following a similar perspective, Eisenhardt (1989) established her method as a positivist orientation aimed at "*the development of testable hypotheses and theory which are generalizable across setting*". Overall, the positivist paradigm is aimed to develop theory in the form of testable propositions, highly focussed on searching for facts that comes from either qualitative or quantitative data sources (Langley & Abdallah, 2011).

On the other hand, the *constructivism paradigm* is drawn from the works of Goia (2002), Stake (1995) and Merrian (1998). These prominent works are highly influenced by grounded theorists such as Strauss & Corbin (1990) and Glaser & Strauss (1968). This paradigm argues that knowledge is socially constructed rather than discovered (Stake, 1995). Stake (1995) mainly conceives qualitative researchers as interpreters and gatherers of interpretations which require them to report their rendition or construction of the constructed reality or knowledge that they gather through their investigation. In the same line, Merrian (1998) says that "*the key philosophical assumption upon which all types of qualitative research are based is the view that reality is constructed by individuals interacting with their social worlds*". Therefore, the primary interest of qualitative researchers is to understand the meaning or knowledge constructed by people, the final product is yet another interpretation by the researcher of other´s views filtered through his or her own (Merriam, 1998). These scientific products are narratives that attempts at the same time to provide closeness to the so called "first-order" participant´s perspectives and to the author´s "second order" interpretations, gathered in abstract themes, producing rich and novel insights (Gioia, Corley, & Hamilton, 2013).

Both the positivist and interpretivist approaches allow for the integration of procedures, tools, and guidelines from the other (Yazan & De Vasconcelos, 2016). This means that we have the flexibility to

combine different epistemological approaches with tools drawn from opposing perspectives. In essence, despite having opposed epistemological foundations, it is possible to complement and enrich both approaches by integrating elements from each (Yazan & De Vasconcelos, 2016).

10.4 Abductive reasoning.

This research falls neither under the data-driven (inductive/constructivist) nor the hypothesis-driven (deductive/positivistic) approaches; rather, it is positioned as an abductive method. Abductive approaches are based on a mutual engagement with empirical data and extant theoretical understanding (Saetre & Van de Ven, 2021). A deductive research approach examines hypotheses, as it revolves around theory-driven investigations. On the other hand, an inductive research approach follows a data-driven path, constructing theory based on empirical data. Lastly, an abductive research approach can be viewed as a combination of both, as it connects empirical data with theoretical frameworks where "*theory and literature are applied in tandem with the raw data to explain the patterns and story behind the data*" (Thompson, 2022, p.1411). While the reasoning logic is abductive, certain concepts and tools from positivistic or constructivist methodologies are also incorporated to enhance the research's efficiency.

As it was described by Sætre & Van De Ven (2021): "*Deductive, inductive, and abductive reasoning each have a role to play in understanding the world, and as our world becomes more dynamic, interconnected, and uncertain the role of abductive reasoning becomes increasingly important*". In this sense, abductive reasoning combines deduction, abduction and induction in the process of building theory, as it is explained by Sætre & Van De Ven (2021):

a. Ideas or hunches that might explain an underexplored phenomenon, problem or question by abduction.
b. Constructing and justifying a theory for the chosen hunch by deduction.
c. Testing the theory by induction.

This research adopts an abductive reasoning approach by investigating anomalies, which are "*novel or unexpected phenomena that existing knowledge cannot adequately explain or poorly understood*" (Sætre & Van de Ven, 2021). This serves as the starting point for abduction, as in the context of collaborative projects, the study of overcoming perturbations remains an underexplored area.

Next, the research proposes hunches that could potentially offer explanations. Specifically, it explores the interplay between equivocality and governance, considering the moderating role of organizational learning, following non-lineal relationships among them (a). The interplay between these three constructs might explain how a collaborative project is able to overcome perturbations. To do this, a

well-established framework (complexity theory) is applied, and subsystem behaviours are deduced based on generative or adaptive systems (b). In this step, the research problem is addressed by applying an existent framework, complex adaptive and generative systems into the case of perturbations. Finally, the methodological process culminates in the development of propositions that emerged from the examination of the two instances of perturbations in a successful case. These propositions offer plausible explanations for the system's behaviours and the interrelationships between the constructs (c).

11. Case Study: LOCUTIOS project.

11.1 Case selection.

Beyond the technical criterion of selecting cases for their revelatory potential, in-depth studies require organizations that provide good access to ensure data richness (Langley & Abdallah, 2011). Accessing to rich data is relevant on a revelatory case study when the focus is to increase the understanding of an underexplored phenomenon (Corley & Gioia, 2004).

The researcher belongs to a university where several collaborative projects have been developed in the last ten years. Most of them have been developed by a consortium of partners belonging to R&D centres and a broad diversity of industries. Their applications cover fields such as robotics, acoustics, technology for learning, architecture, entrepreneurship, urbanism among others. From the period of 2013 to 2019, it has been developed a total of 29 collaborative projects. From that sample, 8 out 29 were considered as a potential sample for our research purposes. That is, a minimum cost of 1 Million euros, 1 year-time bounded and at least 5 independent organizations working together. This first filter is required to capture the most fruitful collaborative projects where intense collaboration was highly required, and the impact of the results (output + outcome) were relevant for the stakeholders.

Among the projects that passed this first filter, a second set of criteria was further applied: (1) exploratory and uncertain nature of the projects, making them highly susceptible to face perturbations, (2) accomplishing the project successfully by reaching positive sponsors' and partners' evaluations, and achieving project objectives (related to the triple constraint), and (3) availability of rich data access (Corley & Gioia, 2004). Following these two steps in the selection process, a successful project, "LOCUTIOS", was chosen. The reasons behind this decision are further detailed:

First criteria: The LOCUTIOS project was a pioneering research project with the objective of creating the first voice simulator, thereby representing significant novel advancements in the fields of simulation and acoustics. Situated at a low Technology Readiness Level (TRL), this project operated in an environment characterized by high scientific uncertainty (Wied et al., 2020). Upfront, the goal of the project was clear for the partners, but the means to reach it were not, leading to increasing scientific uncertainty, making it highly susceptible to face perturbations. As a result, the project encountered two significant disruptions that demanded different reactions; failure to address them would have led to project failure.

Second, as we are looking for projects that were able to overcome perturbations and still deliver valuable outcomes, the successful criteria were a must. The LOCUTIOS project was considered as a success for several reasons. It received the second highest mark in the final evaluation conducted by the European Commission. Then, it was also considered as a success by most of the partners involved

in the project. Most of them acknowledge the project's achievements in meeting objectives and fostering collaboration. Additionally, some partners continued collaborating after the end of the project, as evidence of the positive collaborative results (Chiesa & Frattini, 2007).

Third, the selection of the LOCUTIOS project was also driven by the availability of relevant data due to the close collaboration of the scientific coordinator, two work package leaders, and various researchers that participated in the LOCUTIOS project, with the researcher conducting the case study. This assistance enabled interviews with 10 out of 18 project team members from 6 out of the 7 organizations involved in the project. Additionally, the researcher had access to all the project documentation, that includes memorandum of meetings, technical and executive project reports, among others. The analysis of both sources of data (interviews and documentation) enabled the researcher to build a comprehensive narrative about the events during disruptions. Utilizing diversity of data sources and considering different partner´s perspectives about the facts occurred during perturbations, have contributed to enhance the reliability of the findings by triangulation (Yin, 1994).

11.2 Data collection and data analysis.

Yin (1984), and Corley & Goia (2004) agree on proposing different tools for data gathering such as documentation, archival records, interviews, direct observations, participant observation and physical artefacts. The underlying goal is to increase the reliability by the principle of data triangulation (Yin, 1994). Triangulation means collecting and analysing data from different sources, being interviews and documentation´s review the main ones applied on this research (Yin, 1994). Due to the research is retrospective in nature, semi-structured interviews have been conducted with the main stakeholders in the project. The interviews (13 in total, av. 43.38min) were focussed mainly on “building the story” about what happened during each perturbation, the actions taken to overcome them and how the main constructs have related to each other during these unstable situations. Participants of all the organizations involved in the project have been reached. The interviews were transcribed using the software NVIVO.

The review of documentation of the project includes documentation that are at the public domain (website of the project and EU database: CORDIS) and different documents developed along the project lifecycle such as meeting minutes, project management plan, reports, memorandum of meetings, final deliverables, among others. A total of 75 documents were reviewed. Data collection summary, (protocol of interviews, summary of interviews and documentation) are shown in the Annex of this document.

In part I, an initial round of exploratory interviews was conducted, where the LOCUTIOS project served as one of the units of analysis among other projects. During this phase, the main interviewees

identified two situations of increasing tensions between partners in the project. Subsequently, the LOCUTIOS project was selected as a case study sample, considering the criteria explained previously. Then, the main researcher conducted a comprehensive documentation review to gain a better understanding of the project and to specifically identify the events during each perturbation. In part II, a second round of semi-structured interviews was carried out to delve deeper into the context of each perturbation. The first round of interviews involved the project coordinator, the scientific coordinator and two work package leaders, aimed at providing more detailed explanations of the events and causes during perturbations. Following that, interviews were conducted with the different team members who were involved in each of the perturbations. By the 13th interview, the main researchers determined that the data collected was sufficient to conduct a comprehensive case study and yield valuable empirical insights. Saturation was achieved among all the stakeholders during the interviews.

Pattern matching has been applied as a data analysis technique (Ghauri, 2004). This technique helps to link explicit phrases and words obtained on interviews and documents, with the behaviours of the constructs previously identified on the literature. We conducted a comparison between patterns and categories identified in the data and those proposed in the literature, employing the same rationale for understanding their interrelationships.

11.3 Coding process

We followed the well-known three-stage process of open, axial, and selective coding, building upon and adapting the recommendations of Strauss and Corbin (1998). This approach is well-established in the literature (Seidel, Recker, & Vom Brocke, 2013).

In the initial round of open interviews conducted with the scientific and project coordinator, two primary disruptions in the project and their corresponding responses were identified as critical factors for the project's success. The interviews focused on exploring the concepts linked to these main disruptions, including their origins, sources, contingency actions, and the outcomes tied to each. Our initial analysis stage (open coding) was directed towards identifying concepts and broader categories at a higher level based on the gathered data.

For instance:

> Evidence: "*I remember, we discussed a lot on what computational platform we should be using or if or if we had to have the same one, and of course, people want to stay with what they know, it was difficult to agree to change. And so we had the team in Stockholm that had a very novel and as I perceived it, innovative computational*

platform, but which was met with great resistance from another team who had their own computational platform and didn't want to change that". Project coordinator.

Code: “Different (scientific) interests of the partners in the project”.

Evidence: “In the end, here we almost worked in a co-supervision capacity for WP, along with the scientific coordinator and the project team member, who embedded himself for six months at Group 7. Although I believe it was also an experience for him, it was beneficial for the project as well, because many things progressed while working there, embedded with them for quite some time”.

Code: “Contingency action: personnel exchanges”.

Then, the second step in data collection involves: second round of semi-structured interviews with project the project team members that have participated in each perturbation and the review of project documentation. The objective of this step was to build the story of what happened during each perturbation.

The data collected in the first and the second round of interviews was also analysed following open and axial coding. We have produced well over 70 open codes, as these remain closer to the interviewee´s description. In the second step of the coding process, axial coding, categories were further developed in terms of the main underlying concepts: equivocality, governance and organizational learning. Each of these codes was categorized based on the moment it appeared in the project—whether it occurred during any of the perturbations, before or during the project. This categorization facilitated more effective data analysis.

At this stage we leveraged the research framework developed in the literature (fig.13) to understand the relationship between the three constructs during each perturbation. The open codes were categorized according to situations related to equivocality, governance, organizational learning, system characterizations (behaviours) and system´s results (output / outcome measures). This research framework enables us to analyse how the three main constructs have related to each other during each perturbation, the results obtained after the perturbation and what are the characterizations of the systems. Table 7 is an excerpt of the overall coding list, where open and axial codes are shown. The complete list of codes is further developed in the Annex.

Code nº	Context	Open Code	Concepts	axial code	Subsysten
E1	Perturbation 1	Missunderstandings between partners related to the "product"- MRI data	Missunderstandings	Tensions	Equivocality
E17	Perturbation 1	Missunderstandings between partners related to managerial issues			
E16	perturbation 2	tensions among partners hinder collaboration and knowledge exploration			
E2	perturbation 2	Missunderstandings between partners related to the process - Unification strategy			
E3	perturbation 1	Different interpretations about the project goal	Diversity of interpretations	Equivocality sources	
E4	Perturbation 1	Different interpretations about contracts			
E14	perturbation 1	Different parnter´s expectations about the other´s knowledge	Diversity of expectations		
E20	perturbation 2	The lack of intrinsic motivation as a barrier to build trust between partners	Diversity of interest		
E11	perturbation 2	Different interests (utility) of the partners in the project			
E12	perturbation 2	Different (scientific) interests of the partners in the project			
E9	overall project	Geographical proximity between partners	geographical diversity		
E8	overall project	Scientific diversity of parnters	Scientific diversity		
E6	overall project	Scientific complexity related to the diversity of partners			
E20	perturbation 1	Scientific GAPs			
E10	overall project	Effects of the cultural diversity	Cultural diversity		
E21	perturbation 2	Missunderstandings reduction by authoritive decisions	equivocality reduction	equivocality reduction	
E22	perturbation 2	Missunderstandings reduction by superficial learning			
E5	perturbation 1	Mutual understanding driven by high collaboration into the project and trust among partners			

G12	overall project	Low quality of reporting	Reporting	formal governance	governance
G16	Both perturbations	Positive influence of the sponsor in the project	sponsor implication		
G3	perturbation 2	Different allocation of resources for each partner according to their different interests in the project	Resource allocation		
G9	perturbation 1	Contingency (emergent and unplanned) actions: Hire an external organization	Outsourcing. Contractual changes		
G6	overall project	Ambitious & ambigous initial goal definition	Goal definition		
G7	perturbation 2	Flexibility to adapt the project goal			
G27	overall project	Difficulties to allign Stakeholders into a common goal	Stakeholders management		
G5	overall project	Difficulties to manage different interests in a R&D project			
G8	overall project	Proper initial project plan	project planning		
E13	perturbation 1	Lack of predictability capacity of managers/ members			
G29	perturbation 1	Lack of accuracy of formal agreements	Contractual agreement		
G11	perturbation 2	Contingency (emergent and unplanned) actions: Technical solutions (dividing the problem in parts rather than an unification) decided by the PM and SC	Formal authority		
G28	overall project	Levels of organizations (layers) within the project	Project strucure		
E5	perturbation 1	Contractual implications related to missunderstandings	Managerial issues		

G14	overall project	Increasing supervision along the Project lifecycle	supervision	relational governance	governance
G22	perturbation 2	Lack of personal supervision of PM to each partner at the beginning of the project			
G21	perturbation 1	Improved collaboration thanks to the visits between partners. Improved understanding about technical issues.	exchange resources		
G10	perturbation 1	Contingency (emergent and unplanned) actions: Exchange technical resources			
G23	perturbation 1	Positive results of general meetings on the collaborative capacity of the consortium	Meetings		
G15	overall project	Lack of technical expertise of the PM	Leadership		
G24	perturbation 2	Positive consequences of scientific leadership on consortium collaboration			
G26	perturbation 2	Positive effects of shared leadership between Scientific coordinator and Project Manager			
G2	overall project	Technical knowledge of SC in a diversity of fields			
G25	overall project	The effects of leadership styles on partners´collaboration			
G18	Both perturbations	Interpersonal relationships to build trust	Interpersonal relationships		
G17	perturbation 2	The impact of the EGO into the interpersonal relationships	Scientific EGO		
G19	perturbation 1	Increasing the efforts spent into the project to build trust	Trust		
G4	Both perturbations	Effects on trust of the different partner´s interest			
G31	Both perturbations	Consequences of trust in the collaboration capacity			

Table 7: Example of coding process

Complex adaptive and generative systems prove beneficial at this stage as they allow researchers to conceptualize various types of mutual and nonlinear relationships between constructs. We utilized these theoretical frameworks to classify relationships, diverging from Strauss and Corbin's (1998) paradigm model, which suggests organizing concepts into conditions, phenomena, actions, strategies, and consequences.

By employing open coding, we were able to categorize verbatims into more general concepts. Axial coding facilitated linking these empirical concepts with those originating from the literature and structured within the research framework. Subsequently, the relationships between these concepts were analysed during each disruption as a means to comprehend responses to disruptions.

The third phase involved selective coding, in which we integrated the primary categories and relationships to construct a more comprehensive theoretical framework (Strauss & Corbin, 1998). We examined how these three constructs interrelated during both disruptions. The outcomes derived from this process enabled the authors to propose plausible explanations (in the form of propositions) for the relationships among the three constructs during each disruption. We have identified how different concepts of each of the subsystems have interrelated to each other during each perturbation.

For instance; during perturbation nº1, **G18 (**interpersonal relationships to build trust) that belongs to the concept of "interpersonal relationships" as an implication of the "relational governance" (Cao & Lumineau, 2015) (category) have been related to **E5** (equivocality reduction).

Utilizing abductive reasoning and drawing upon the collected and analysed data, we offer interpretations regarding the interrelationships among constructs and conduct a thorough analysis of the chain of causes and effects. In the previous example, **G6** (ambitious & ambiguous goal definition) led to **E1** (Misunderstanding about the "product"), and then **G18** have been related also with **E5**. In this sense, multiple types of relationships have been identified among subsystems.

The final phase in the theory-building process involved interpreting and inferring the underlying issues associated with these relationships, focussed on the proposed research framework. This was done to bring the discussion closer to a theoretical context. In other words, how the three constructs/ systems have interrelated during each perturbation to provide plausible explanations how resilience have been achieved in each case. In the following sections, the relationships between subsystems during perturbations are further explained.

The case analysis is structured as follows: Initially, the description of the LOCUTIOS case, outlining the key actions that facilitated the project's resolution of each disruption. Subsequently, the case analysis focusses on each disruption separately, viewed through the lens of the research framework outlined in the previous section.

To enhance readability, the researcher highlights the main verbatims associated with each concept and open code. The goal is to present sufficient evidence supporting the researcher's interpretation and enhance the narrative surrounding the actions and outcomes linked to each disruption (Seidel et al., 2013).

11.4 LOCUTIOS: Case description.

11.4.1 LOCUTIOS: Project description.

The LOCUTIOS project has been funded by the European commission (3.5M euros) in the Seventh Framework Programme. The main objective was to develop an extensive unified-domain simulation of the human voice. According to the Technological Reading Level, it was at the 2º level (out of 9), being highly scientific exploratory in nature. The research centres that formed the consortium belonged to different scientific fields such phonetics, speech modelling, neural motor control, biomechanics, acoustics, and computational multi-physics. They have never collaborated before the project, what required all the parties to learn how to work together to co-develop a joint output. The project has started on 2013 and it finished in 2016, getting the second highest mark according to the

evaluation of the European Commission and the partners involved were able to develop more than 50 articles in top journals as a project result.

As it is described in the abstract of the proposal, the project aimed to develop a novel scientific progress in the field of voice simulation, a new voice simulator:

> "E*veryone needs their voice, and speech has a pivotal function in modern society. A detailed, working model of the voice would contribute to the human atlas and would find profound applications in fields such as speech technology, medical research, pedagogy, linguistics and the arts. But the physics are very intricate: we make the sounds of speech, song and emotions using multiple mechanisms; and these are under exquisite control, through muscle activation patterns acquired from years of training. Physically, voice involves complex interactions between laminar and turbulent airflow; vibrating, deforming, colliding elastic solids; and sound waves resonating in a contorting duct. So far, these mechanisms have had to be studied one at a time, using disparate tools and often gross approximations, for each of the subproblems. Now, advances in computing techniques suggest the possibility of simulating the entire voice organ, including its biomechanics and aeroacoustics, in a unified numerical domain. This major computational challenge would bring research and education much closer to reality. In the LOCUTIOS project, we seek to build a new voice simulator that is based on physical first principles to an unprecedented degree. From given inputs, representing topology or muscle activations or phonemes, it will render the 3-D physics of the voice, including of course its acoustic output. This will give important insights into how the voice works, and how it fails. The goal is not a speech synthesis system, but rather a voice simulation engine, with many applications; given the right controls and enough computer time, it could be made to speak in any language, or sing in a style. The model will be operable onlline, as a reference and a platform for other to exploit in further studies. The long-term prospects include natural speech synthesis, improved clinical procedures, greater public awareness of voice, better voice pedagogy and new forms of cultural expressions*" (Proposal submission form).

After more than 7 years of its finalization, the technology developed through the project has acquired remarkable relevance in the scientific community. The project has been developed by 7 research centres that belonged to 5 independent organizations, as it is outlined in the graph Figure 14. The partners belonged to 4 different countries: Sweden, Germany, France and Spain, increasing the

complexity of collaboration due to geographical and cultural diversity. The project consisted of 8 Work packages developed collaboratively by different organizations (Figure 13)

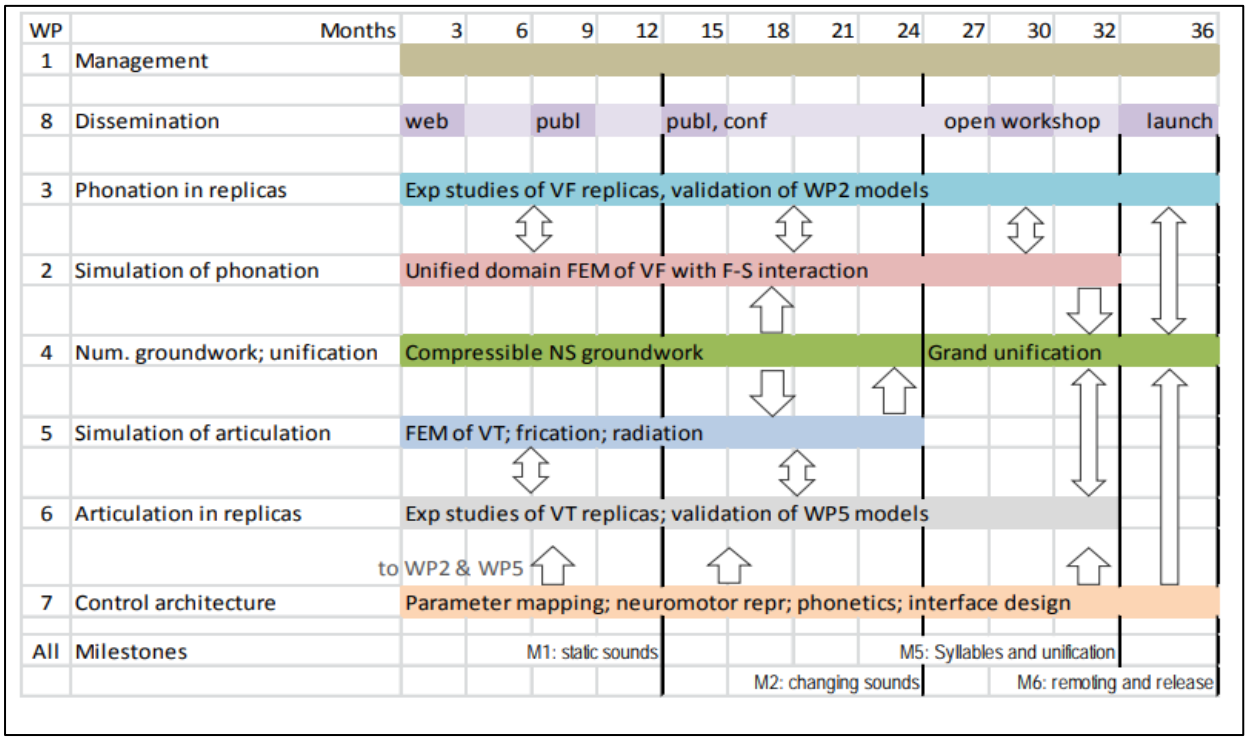


Figure 13: Work Breakdown Structure (WBS) LOCUTIOS project

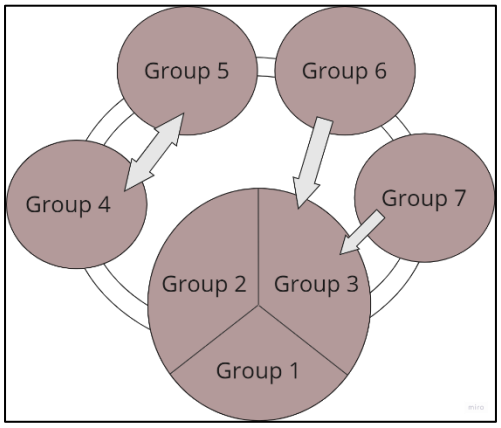


Figure 14: Project organizational breakdown structure. LOCUTIOS project

The project's primary challenges revolved around the integration of vastly disparate knowledge domains. For example, it required collaboration between simulation efforts led by mathematicians and speech processing led by voice engineers, as well as biomechanics led by structural engineers. Each of these disciplines brought its distinct background, knowledge framework, and methodologies into play. This undertaking was a scientific endeavour demanding intensive collaboration to achieve a

common outcome: a voice simulator that combined the collective input of all partners. Consequently, the alignment of partners' interests, expectations, and knowledge domains emerged as a critical issue to deal with, demanding deeper levels of cooperation and coordination.

Before delving into the case's evolution, another important aspect to consider is that not all partners were engaged in every task during the project's lifecycle. Rather, collaborative teams were established within or between Work Packages (WP), typically comprising two or three organizations. This structure is closely related with the notion of "couplings" or interconnections among distinct organizations operating at various levels (Klessova et al., 2020). The extent of collaboration, the array of challenges encountered, and the learning behaviours varied across each scenario. To shed light on this, the ensuing Table 8 outlines the primary levels of analysis.

Level of analysis.	Work Package	Organizations involved	Intensity/ frequency of collaboration
Executive level	Overall project	Organization´s leaders	General annual meeting
WPs Couplings	WP 2 - 3	Group 3 - 5	4 technical meetings a year / ad-hoc communication
	WP 5 - 6	Group 4 - 6	
	WP 4	Group 6 - 7 - 3	
	WP 7	Group 1 – 6	
	WP 6 - 3	Group 4 – 5	
Intra-organization	All	All	Weekly basis

Table 8: Levels of interconnections between partners. LOCUTIOS project

As it was discussed in Klessova *et* al (2020), the collaborative capacity of the overall project depends on the collaborative capacity of the couplings, the interconnections between small numbers of companies that form collaborative teams. Most of the technical issues occur at this level as the intensity of collaboration is higher than executive levels.

After a comprehensive review of all technical and executive reports, as well as two interviews conducted with the scientific and project coordinator (Anex I), both the researcher and the interviewees arrived at the consensus that the project encountered two main disruptions. This conclusion is rooted in the observation that in both instances, had these issues not been resolved, the project would have been at risk of failing to achieve its objectives. While there were also other instances of conflicting situations among partners at both the executive and coupling levels, these

were ultimately disregarded, as they did not pose a significant threat capable of bringing the project to the point of failure.

Furthermore, in both situations, the European Commission issued an alert, underscoring the significance of the challenges and compelling the partners to take decisive measures. Subsequently, it is noteworthy that in these two particular cases, executive-level meetings were convened to deliberate and make strategic decisions on the course of action. In this sense, these two instances of perturbations brought the project to situations that might be considered the edge of chaos, limited instability. The unit of analysis will focus specifically on the times of perturbations and how both teams were able to overcome them. In the following Figure 15 a qualitative sketch aims to show visually the level of instability of the project during the project lifecycle.

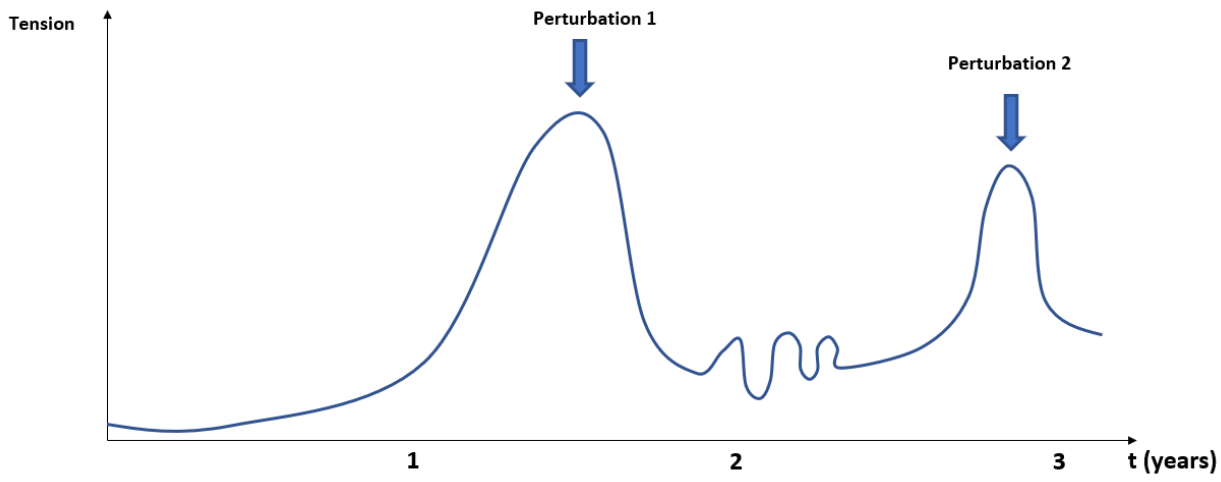


Figure 15: Variable levels of instability and tensions among partners during the project. LOCUTIOS project

11.4.2 Analysis and detection of perturbations.

Examples of disruptions can be found almost everywhere, such as the famous COVID-19, wildfires, hurricanes, typhoons, cyclones, prolonged periods of dry weather, climate change or armed conflicts (Naderpajouh et al., 2020). At the project level, a perturbation can be considered as an unexpected issue that could have disastrous effects and cause, in principle, unbounded damage (Helbing, 2013). This conceptual definition might lead to a diversity of interpretations about what a “perturbation” exactly means. Instead of delving into various typologies of disturbances, such as shocks or stressors (Helbing, 2013), this research regards disruptions as unforeseen issues that significantly disrupt or challenge the project's continuity or the achievement of project´s results.

In this sense, we considered "perturbations" as unforeseen issues, whether originating from external or internal sources, that had the potential to pose challenges to the attainment of triple constraint

objectives (cost, time, or project scope) or that have direct effects on sponsors and stakeholder´s satisfaction. Both aspects are the main measures of project success (Padalkar and Gopinath, 2016). Perturbations could also lead to conflicts among partners, and their failure to be resolved would have had a significant adverse impact on achieving the project's objectives.

According to this reasoning, two relevant perturbations have been detected. The first one related to the main geometries of the project, and the second one, related to the unification of the simulation codes.

Perturbation 1: Geometries

The primary focus of the LOCUTIOS project during the first year was to develop accurate geometries for the vocal tract and vocal folds. These geometries were essential to initiate simulation activities, allowing the teams to explore various aspects of airflow within both the vocal tract and the folds. The GROUP 1 was the leader of this WP (WP7), and also the responsible for providing these biomechanical geometries to two other groups, GROUP 6 and GROUP 3. However, the project plan agreed upon by all the organizations did not provide clear specifications regarding the required level of accuracy for these geometries.

Initially, GROUP 1 operated under the assumption that the pre-existing geometries would adequately serve the project's requirements. Meanwhile, GROUP 6 relied on the belief that GROUP 1's contributions would align with their own specific needs. As GROUP 1 was starting to supply the geometries, GROUP 6 gradually realized that the provided geometries did not align with their requirements. This led to a clear recognition of the mismatch between their expectations and the actual outputs. Unfortunately, GROUP 6 were also unable to specify the degree of accuracy required, as it was not part of their tasks. Therefore, the outputs delivered by GROUP 1 did not meet the needs of GROUP 6, but the latter was not able to define their requirements more precisely. This incident is an example of how information can be interpreted in multiple ways based on the background of the partners, who belonged to different scientific fields such as biomechanics and acoustics.

> *“The MRI (Magnetic Resonance Imaging) data at our disposal is not scant, it is much more arduous to adapt to the purposes of LOCUTIOS than was initially anticipated (…). This has caused significant delays for the static vocal tract geometries to be provided by WP7 for WP3, WP5 and WP6. "* [Project Progress Report 1] (Month 12).
>
> "*We used models from other projects to try to generate these shapes, and then when we have done that with a great amount of effort, the next partner said, “Oh no, no, these won't work, we need them much smoother”. Alright, exactly how smooth do you*

want them? And they could not answer that. They said "well, you know, smooth". Project coordinator.

The main underlying factor behind this disruption stemmed from a lack of shared comprehension regarding the definition of "accuracy" within their respective domains of biomechanics and acoustics. This lack of mutual understanding persisted for nearly a year, highlighting the inherent unpredictability often encountered in collaborative scientific endeavours. Both teams struggled to anticipate the technical prerequisites of the other. The clarity that one group possessed was clouded in uncertainty for the other, and vice versa.

On the one hand, the biomechanics team did not understand why the simulation team expressed dissatisfaction with the delivered geometries. Conversely, the simulation team encountered difficulties in articulating the precise degree of accuracy required, as their expertise did not encompass geometry development.

"*The difficulties stem essentially from three circumstances: (a) the vocal tract airway 'object' in the aerodynamic FEM (Finite Element) simulations is a 'non-object' in the biomechanical domain, defined only as any space(s) not occupied by solid structures; (b) that, as meshes are made to move, contacts, intersections and narrow angles inevitably appear that threaten the stability of the FEM solutions***"** [Project Progress Report 1] (Month 12);

"Our work package did not initially have an understanding of what was required for the airflow simulations and the work package working with the airflow simulations did not quite have a biological or articulatory understanding of what the complexities are when you are looking at this tube" WP7 Leader

The convergence of different disciplines can give rise to unpredictable knowledge gaps that can disrupt a project. In this case, scientists from the biomechanical and simulation field had their own understanding of the meaning of the information required. While both research fields had their own interpretations of the meaning of MRI data, a knowledge gap was identified in terms of what the other team conceives about this output and the process to develop it. This knowledge gap became evident when both teams could not reach common understanding about the level of accuracy required of that data.

At the end of the first year, the project received a red flag from the sponsor related to this issue.

"*We had a red flag from the European Commission related to the geometries*". Scientific coordinator.

"*So, this was definitely an issue between the work packages, and this is what made it sort of difficult to solve*" Project coordinator.

Had the involved teams not resolved this issue, the project's continuity would have been severely compromised, as these geometries served as the foundation for the subsequent development of various simulations. Not developing these geometries would had a direct (and negative) implication in the subsequent development of simulations, challenging the continuity of the project according to the plan.

The tensions between partners had escalated as they could not reach a common understanding about the accuracy of geometries. These situations might be considered as an edge of chaos situation (Gell-Mann, 1994): stability has been challenged as the partners could not continue working in the manner where they were working on, bringing the project to a situation of temporal instability, forcing it to react and change.

Perturbation 2: Unification.

The final work package of the project (WP4) was aimed to integrate separate simulation codes developed by two teams: GROUP 7 and GROUP 3. By the end of the third year, the project faced difficulties in figuring out how to combine the different simulation codes for the vocal tract and vocal folds into a single platform, as outlined in the project plan. During the project, each team concentrated on their specific work packages (WP2 and WP5) respectively, which revolved around individually on the vocal tract and vocal fold simulations. There were minimal interactions between these two teams, even though their responsibility was to eventually integrate all the developments made over the course of the project.

In the third year, both teams initiated the process of integrating their code sets. However, this integration posed a significant challenge as the teams had applied distinct methodologies, tools, and platforms to develop their own simulation. At the end of the third year, there were two simulations codes, developed in different platforms and following different methodologies.

"*There were two codes. We have the code made by Group 7 and the one made by Group 3. There were not easily exchangeable*" WP5 team member.

The adaptation of one team's code to align with the other team's platform required significantly more effort from the sending team, in comparison to the receiving team.

"*I remember, we discussed a lot on what computational platform we should use. Of course, people want to stay with what they know, it was difficult to agree to change.*

We had the (GROUP 3) that had a very novel and, as I perceived it, innovative computational platform, but which was met with great resistance from another team (GROUP 7) who had their own computational platform, and they didn't want to change that". Project coordinator.

Both teams belonged to the simulation field, and they could reach easily common understandings about technical issues. However, they belonged to different "school of knowledge", as they were applied different techniques to develop simulations. One team was perceived as more traditional, sceptical and stringent in their approach, and the other was perceived as more innovative but also, less mathematically grounded.

"*There was a sort of tension between Group 3 and Group 7. And the reason was that the group 3 has been controversial in the field because they do things a different way. And some people consider them to be sloppy. But on the other hand, they were very creative and did some novel interesting things. But I remember that there were people on Group 7 that did not believe in the methods of the Group 3 team" (…) "So Group 7 was more sceptical, but perhaps also more stringent in their approach. And the Group 3 party were more visionary, but perhaps not so scientific or mathematically grounded* " Project coordinator.

After more than two years of the project, they had to unify both solutions, but they have found many issues that impeded a quick and fast unification, as each one of them had developed their own simulation using their own technique and platform, where the outputs were not easily exchangeable. This increased the tensions between them as they could not reach an agreement about what is the best platform to conduct the unification, highlighting the weak points of the other´s ideas.

"They didn't say, "No, we don't want to do it like that", but they formulated it in a way like "Oh no, it's not possible to make sure we did in the realistic framework". And I thought it should actually be two of them". WP3 team member.

Recognizing this challenge, a dedicated meeting was held to decide a path forward, as both teams were unable to collectively reach a consensus, none was willing to give up in this negotiation. This scenario serves as a prime example of how internal dynamics can disrupt a project, leading it into a situation of temporal instability. Since the ultimate project goal was to deliver a unified solution, failing to reach agreements on how to unify it might be considered as an edge of chaos situation (Gell-Mann, 1994). This scenario was characterized by temporal instability, compelling the teams to make changes.

The intrinsic unpredictability of scientific endeavours and the difficult task of reconciling distinct knowledge frameworks and interests within the knowledge field of simulation contributed to the issue. This case underscores the complexity that arises when a collaborative undertaking involves individuals with diverse backgrounds and scientific interest, potentially giving rise to unpredictable disruptions.

> *"How do you transfer the data? How do you cut some of the domain to just use the acoustic simulations? and so on. It's a difficult task and just to switch everything to another platform is complex. I understand both parties wouldn't want to do that if this took much work. So, if there was some tension and that's quite normal, I'd say, nobody would want to do that of course"* Project team member WP4.

These issues have worsened tensions between the partners involved, and if these tensions were not reconciled, the project would not have been able to finish meeting the initial objectives. Two strong positions were competing to reach a common agreement that would directly affect their interests and, implicitly, the resources invested in the project. During the unification meeting, the underlying tensions between partners became salient tensions. Both teams were not able to reach an agreement by themselves, leading the project to the edge of chaos. If the teams involved had not addressed this issue, it could have posed a significant threat to the project's continuity and might even have jeopardized approval from the European Commission, as the final outcome was expected to encompass the seamless integration of various simulations.

Summary of perturbations.

In both instances of perturbations, the inherently uncertain nature of collaborative projects pushed the project to situations of limited instability, that might be considered as the edge of chaos. In the first case, the project's plan had not explicitly defined the required accuracy level for the geometries. Both teams involved in WP7 did not consider beforehand that would have been an issue about geometries. These geometries held different meanings for the biomechanics and simulation teams—representing a tangible object for one and "*a space no occupied by solid structures*" for the other. The diversity of understandings about what the geometries meant and how to develop them emerged as an unexpected issue that seriously affected the continuity of the project.

In the second case, two distinct scientific knowledge schools in the field of numerical simulations collided. One was grounded on pioneering and innovative methods, while the other leaned towards scepticism and mathematical rigor. Once they have realized they have to integrate both sets of codes, unforeseen technical complexities surfaced because of combining these divergent methodological approaches. The challenge of reconciling both sets of codes, coupled with both partners' reluctance

to abandon their respective approaches, heightened tensions among the partners. If these disagreements had not been resolved, the project would not have been able to deliver a unified solution.

In both instances of perturbations, had the project not undergone changes or adaptations, failure would have been a probable outcome.

11.4.3 Actions to overcome perturbations

It has been identified two instances of perturbations, based on the analysis of interviews and project´s documentation. The next step is to analyse the reaction and adaptation in each one of the cases, that allowed the project to continue its progress. A set of several actions have been taken in each case, as these are described in the project reports and explained by the interviewees. However, after an analysis of most of them, the researcher decided to focus on those actions that have significant impact on the results. In other words, in those actions that, if they had not been carried out, the project would have had difficulties on overcoming the disruption the way it has.

Two primary actions were identified for each perturbation that facilitated the teams' ability to surmount them. To enhance the analytical rigor, a pattern matching technique was employed to establish connections between the actions found in the data and concepts previously established in the literature. Rather than proposing a list of actions derived from open codes, a second-order analysis (Corley & Gioia, 2004) was conducted, with a focus on aligning the actions identified in the data with actions referenced in the existing literature. This approach allows the research to advance and positions the analysis within a more firmly established theoretical framework.

<u>Perturbation 1: Geometries</u>

1) Exploratory knowledge search strategy (by involving external actors) (Eriksson et al., 2016).

Knowledge search strategies are essential in bridging knowledge gaps (Eriksson et al., 2016). These enriches the knowledge pool by adding different variations that provide alternatives to similar problem (March, 1991). Explorative strategies enable flexibility in search boundaries, facilitating the sharing of diverse interpretations and the search for new and innovative alternatives to fill knowledge gaps (Eriksson et al., 2016).

An extraordinary meeting was conducted by the consortium of partners to address the geometry problem. During the search for a solution, a researcher (unrelated to WP7) discovered on the internet that a Canadian team outside of the LOCUTIOS project was also developing similar geometries. The WP7 leader accepted such recommendation and subsequently established a collaborative partnership with the Canadian team. This collaboration persisted during the project and helped to accelerate the

development of the geometries. This is an example of an exploratory search strategy, trying to tackle the knowledge gap by considering different alternative solutions.

> *"Contact was made with a Canadian team of researchers, at the University of British Columbia, who for over 10 years have been developing a general biomechanical modelling toolkit known as ArtiSynth (..). We have therefore recently initiated a transatlantic cooperation that we believe will fast-track us to a more complete model than was foreseen in the DoW (Declaration of Work)" [*Project Progress Report 1] (Month 12).
>
> *"We started to try to find different solutions and we had some intermediate solutions that did salvage the project at some steps. When we got this Canadian team involved, we could use the model that they had previously created, so we started to gain speed. And once we had that in place, we worked quite efficiently, and we definitely had a much higher pace in what we did". WP7 Leader.*

2) Bridging ties (by exchanging technical resources) (Tiwana, 2008).

A bridging tie functions as a connection that unites actors separated by a structural hole (knowledge gap), enabling them to explore and integrate knowledge from different domains (Tiwana, 2008).

In the context of the project, both Group 1 and Group 6, which were both involved in and influenced by the geometries' development, recognized their limitations in achieving a shared understanding regarding the necessary data. To tackle this challenge, Group 6 has sent a technician to work on-site at Group 1's location. The main objective was to develop mutual understanding about the meaning of data and how to obtain a geometry that met the requirements of both teams. Following an 8-month exchange program, both teams were able to bridge the two scientific fields (biomechanics and simulation) and jointly develop the knowledge required for the necessary geometries.

> *"From November 2013 (Month 8) to May 2014 (Month 15) researcher xx (Group 7) is a visiting researcher at Group 1. This link between participants has been very productive, and has facilitated considerably the communication between WP5, WP2 and WP7". [*Project Progress Report *1] (Month 12).*
>
> "*And that was solved by having a very close collaboration between our work package that was going to provide all the geometries and the work package that was going to use them. So, we had it between both senior researchers and, junior researchers in each of the work packages, and they worked very closely together to know how we*

can solve this. And that was thanks to have a researcher of the other team in our lab" WP7 Leader.

"*He (technician) was embedded at Group 1 for eight months and it was very beneficial for the project, because many things were progressed by working there, immersed with them for a considerable period of time*". WP 6 team member.

To overcome the perturbation, the project took two main actions: involving a third organization that was not initially included in the project and exchanging technical resources. These actions helped the project solve the technical issues related to the geometries and also, to improve the degree of collaboration between both groups after the perturbation.

"The positive thing was that in the end we overcame most of these problems and we achieved much more than we would have if we had a smaller priority or had involved teams that work closely together from the start. We got all the different perspectives that we had, new insights and new results that were related specifically to the fact that people came from many different areas". WP7 leader.

In the first case, the teams involved in the perturbation were able to overcome it. However, after the perturbation we can associate specific performance results in terms of efficiency and value. Regarding the first, related to the triple constraint, (scope - time and cost), the WP7 required more resources and lasted longer than was initially estimated. The exchange of 8 months of one researcher in addition to a new contract with a third party clearly affected the initial budget allocated to this WP. This is an inference made by the researcher, as the information related to cost estimated versus real resource´s allocation was not available for this research. The second aspect, related to time, the first milestone of the project was to deliver the geometries at the end of the first year, and these were released with the desired accuracy later, around month 18th. However, in terms of scope, after the perturbation, the Group 7 was able to deliver the geometries according to the requirements of the other teams involved, achieving the objectives in terms of scope.

Regarding the second measurement, the value added by the outcomes to the stakeholders, the results were positive and even better than expected. After the perturbation, the level of collaboration between both groups increased, enabled by the trust created during this process and it resulted in an increased number of articles published by both teams together (9 joint articles). Bridging two very different disciplines enabled them to create a joint knowledge, highly valuable for the scientific community as it combines biomechanics with airflows simulations, a novel outcome for the state of the art.

"*They were visiting each other's lab for a longer period of time so that they were actually working continuously together for a longer time" (…) It led to a very close collaboration for several years and resulting in several different high-profile publications. So, the outcome was very successful.* WP7 Leader.

"*After the crucial meeting in Barcelona, the level of collaboration significantly improved*" Scientific coordinator.

Perturbation 2. Unification process.

1. Understating and Multifunctionality (by reducing the project´s objectives and scope) (Wied et al., 2020)

These actions imply reducing the threshold of acceptable performance or even setting multiple modes of acceptable performance (Wied et al., 2020).

The teams came to the realization that they were unable to achieve the project's objectives within the designated timeframe. Delivering a completely unified solution, in a single platform, would require completing several complex technical tasks and would also increase the cost and time associated with the work package 4. These issues prompted the partners to agree on reducing the scope and goals of the project to make them more attainable.

"*Each one of them had their own computational platform and they didn't want to change that. So, we split the problem up, I suppose, in different aspects of the problem. We never really achieved the fully unified solution that we were hoping to achieve. We decided we would have liked to have it all work together, but at the end we had to say that we did a partial solution to that problem, and we can present an almost complete solution to the problem*". Project coordinator

2. Exploitative knowledge search strategy (by developing a compromise solution) (Eriksson et al., 2016).

Interorganizational teams often rely on past experiences and existent knowledge to make decisions, which can limit their ability to generate new ideas and interpretations. This can lead to a "lock-in" effect, rigidity, and disputes among partners. Exploitative knowledge search reinforces this approach, resulting in a narrow focus on expertise and applying proven solutions from past experiences to increase problem-solving speed (Eriksson et al., 2016).

In this case, the coordination team suggested a compromise solution to overcome conflicting tensions. The solution aimed to exploit the existing outputs of the partners, rather than exploring alternative

solutions. The proposal was for each team to develop a partial solution using their own platform, which would result in two partial solutions and two codes that would be partially integrated into a single platform. Consequently, the final solution required two coding steps, rather than a single and unified process, as it was considered in the initial plan. This approach allowed each team to continue working on their own code, exploiting their own knowledge.

> " *The final unification was not a merging of codes. There was the Group 3 code and the Group 7 code separately. Then, an attempt was made to bring together these different codes in different steps, but they were not fully unified. If someone wants to run a simulation, he will have to make two steps, first in one platform and then in the other one*" Project team member WP5

> "*And the result was not what you might think of as a unified solution because it simply was a compromise. I don't think it was a bad compromise".* Project team member WP3

To overcome the second perturbation, the project has taken two main actions: reducing the project scope and goal and developing a compromise solution based on the existing knowledge of each partner (exploitative search strategy). These actions helped the project solve the managerial issue related to how/where unify the solutions. However, the level of collaboration between partners even decreased after the perturbation.

In the second case, the teams facing the disruption managed to overcome it as well. However, the consequence of this situation led to different project´s results in terms of efficiency and value compared to the first case.

In terms of efficiency, the coordinating team had to reduce the project's scope - moving from a fully unified solution to a partially unified one. This adjustment was necessary to meet the strict time constraint set by the European Commission. As this work package marked the project's conclusion, the pressure to meet time deadlines led the partners to narrow down the project's focus. This adaptation suggests that, contrarily to the first perturbation, partners accomplished their assigned tasks within the specified time and resources, as it was established in the project plan, but with a reduced scope.

On the other hand, in terms of value, the results diverged from the first perturbation. In this case, both partners showed significant reluctance to collaborate together. After the disruption, collaboration between the partners further decreased, as there was no need for joint efforts. Two distinct scientific approaches within the simulation field resulted in separate outcomes rather than a combined solution. The number of collaborative articles between the teams was much lower than in

the other couplings, and there is no evidence of post-project collaboration between them, despite their shared field.

Table 9 and Figure 16 summarize the events occurred during the perturbations.

Perturbation	Description	Sources	Actions (resilience)	Theoretical concept
Perturbation nº1	One team is not able to deliver an output that fits with the requirements of other WPs.	- Diversity of knowledge backgrounds (Different understanding about what/how geometries should be delivered) (Frishammar et al., 2011)	1.Exchange technical resources to create bridges that enable the creation of joint knowledge.	Bridging ties enabling knowledge integration (Tiwana, 2008)
			2.Involve external partners that fill the knowledge gaps.	Explorative knowledge search (Eriksson et al., 2016)
Perturbation nº2	Two teams do not reach agreement about how/ where to unify 2 simulation codes	- Different scientific interest in the project (Calamel et al., 2011) - Diversity of knowledge schools within the same knowledge domain (vom Brocke & Lippe, 2015).	1.Reduce the scope and goal of the project.	Understating & Multifunctionality (Wied et al., 2020)
			2. Develop a compromised solution to satisfy all parties.	Exploitative knowledge search (Eriksson et al., 2016)

Table 9: Summary of perturbations and contingency actions. LOCUTIOS project

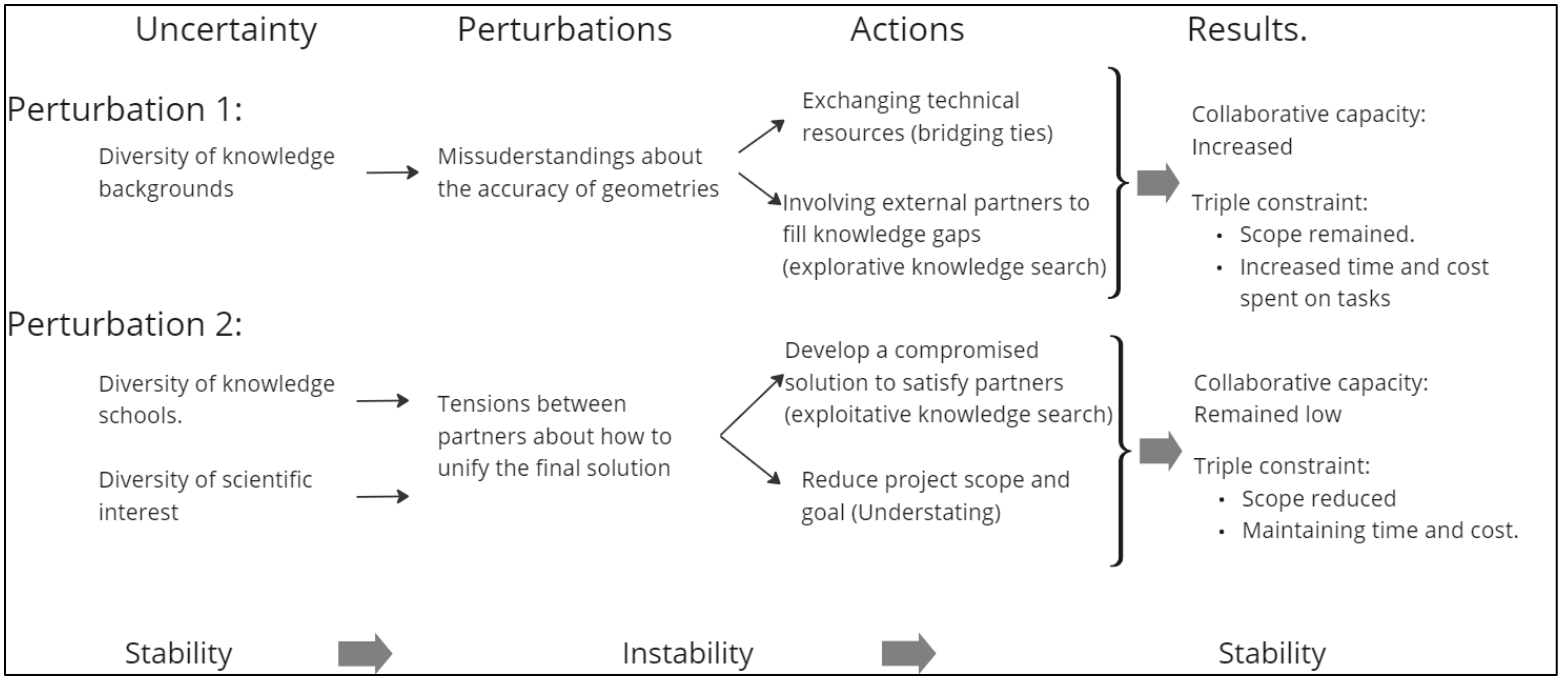


Figure 16: Summary of perturbations/ actions that enabled resilience. LOCUTIOS project

12. LOCUTIOS Project: Cross-case analysis.

Two instances of perturbations have been identified and analyzed, encompassing their causes and the actions that facilitated their resolution. In this section, we delve into an examination of each perturbation (as unit of analysis) and its corresponding response, following the proposed framework established in section 9.

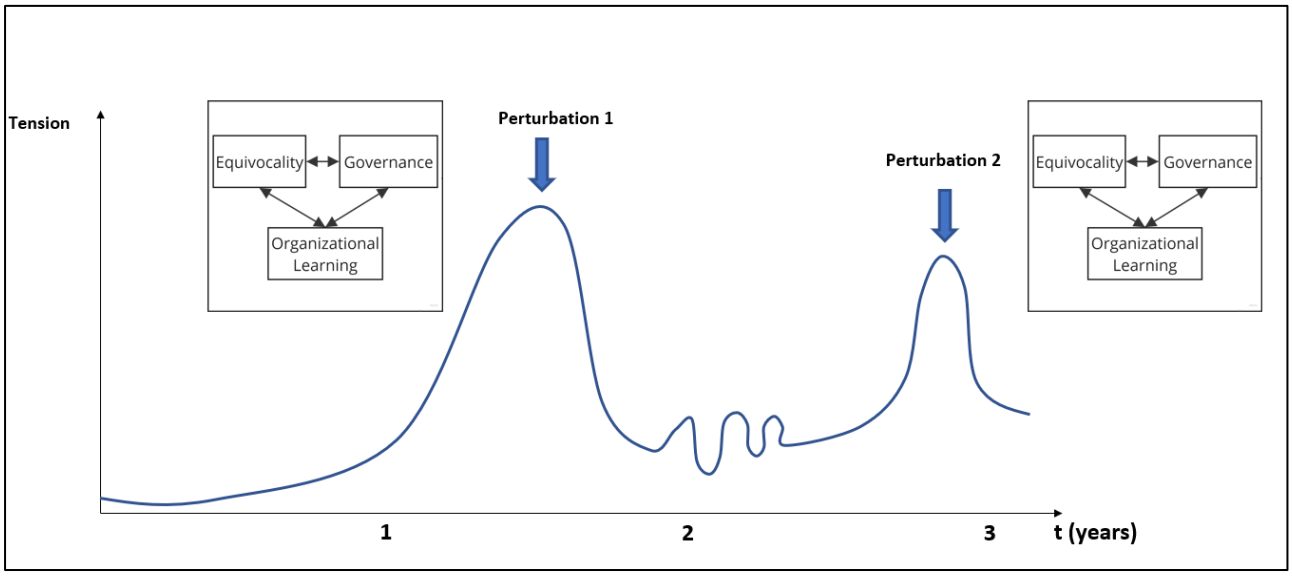


Figure 17: Research framework proposal to analyse two instances of perturbation. LOCUTIOS project

12.1 Perturbation 1. Complex generative system.

12.1.1 Subsystem´s behaviours and interrelationships.

During the first perturbation, neither team was able to reach a mutual consensus about the accuracy of the geometries (MRI data). The formal agreements and the initial plan were insufficiently clear to specify the level of accuracy required, resulting in an increase in the diversity of interpretations (equivocality) among partners due to their different backgrounds (acoustic & biomechanical). The same information, geometries, was interpreted as an "object" for the simulation team and as a "non-object" for the biomechanics. The latter was in charge of developing geometries with a level of accuracy that the former was not able to define. The variety of interpretations pushed the project towards a situation that might be considered as the edge of chaos, compelling the partners to seek solutions within and beyond the project's boundaries to overcome it.

> "*The description of WP7 in the DOW (Declaration of Work) does not point out extracting vocal tract shapes as a main task, the MRI images are a source of information needed in order to perform the actual task of generating a parametric vocal tract model".* Project Technical Report (M12)

> *"We were assuming that all the data could be used because it had been used in the previous project and it had worked. We were not from the numerical air simulations field, so we didn't know the resolution that was required of the team that had been working on these numerical simulations did not know what they could expect from these images, so this was definitely an issue between the work packages and this is what made it sort of difficult to solve"* WP7 Leader (GROUP 1)

In this context, the absence of detailed specifications in the formal agreement (DoW) (formal governance) concerning the level of geometric accuracy and the methods for its development resulted in a greater range of interpretations, leading to situations of equivocality. In this sense, a limitation of formal governance led to an increase in equivocality situations.

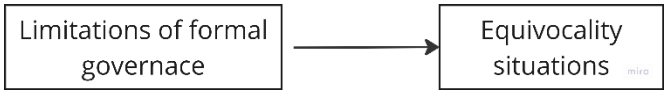


Figure 18: Perturbation 1: Relationship between governance and equivocality

Two actions were taken to address this problem, involving a third party in the project and exchange technical resources. Both were not initially considered in the contractual agreements. The first solution, which entailed collaborating with a third party (the Canadian team), demonstrates an honest acknowledgment of the limitations within Group 1. They recognized that their deliverables were falling short of expectations. Engaging an external organization enabled them to revaluate their own knowledge foundations and methodologies in order to advance the project. The second measure, involving the exchange of a technician to bridge knowledge gaps, signifies a shared realization between both teams that their mutual understanding was hindered by differing in knowledge domains. Investing time and resources to establish a bridge that facilitates the convergence of these knowledge domains was a responsive action that arose organically from the partners. This approach was taken to effectively address the existing knowledge gap.

Equivocality situations compelled the partners to seek solutions both within and outside the consortium of partners to address them. These actions allowed both teams to delve into various knowledge domains and methodologies. Researchers from the biomechanics field had to gain an understanding of what these geometries represented for the simulation teams, and vice versa. This exploratory process to gain knowledge from different domains was made possible through resource exchange and the engagement of a third party, which contributed to a re-evaluation and enhancement of each partner's existing knowledge. In this regard, situations of equivocality sparked a process of knowledge exploration.

"WP7 will continue to have difficulties to fulfil the tasks actually described in the DOW. We must hence find a solution that provides the other WPs with a vocal tract geometry that is adequate for their simulations/measurements, but on the other hand lets WP7 focus on the work we are required to do within WP7" Technical Report (M12)

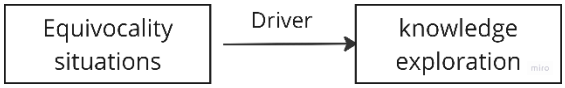


Figure 19: Perturbation 1: Implications of equivocality into knowledge exploration activities

Both actions significantly sped up the process of developing geometries. Formal governance was modified by including more parties in the agreement and allocating additional resources for the exchange program to the WP7.

*"Contact was made with a Canadian team of researchers, at the University of British Columbia, who for over 10 years have been developing a general biomechanical modelling toolkit known as ArtiSynth (..). We have therefore recently initiated a transatlantic cooperation that we believe will fast-track us to a more complete model than was foreseen in the DoW" [*Project Progress Report 1] (Month 12).

Then, thanks to the exchange program, the enhanced personal relationship between the technicians from each work package resulted in better collaboration, as they began to comprehend each other's requirements and challenges in their respective fields. The exchange of resources facilitated mutual understanding, bridged scientific gaps, and increased trust between the partners.

In this manner, relational governance (in the form of exchanging technical resources) compensated for the initial limitations of formal governance, converting initial resource´s allocation into real partner´s contribution (Benítez-Ávila et al., 2018). Formal governance (in the form of contractual agreements) has been also adapted to address the issue of the geometries (by involving external parties). In this sense, both relational and formal governance acted as enabler/ compensator, complementing each other to address unexpected issues (Benítez-Ávila et al., 2018). The misunderstanding about geometries forced the teams to find solutions through a process of knowledge exploration (Eriksson et al., 2016). This exploration was also enabled by the complementarity between formal and relational governance. There was governance´s adaptations, including changes in formal agreements and an increasing dependency on relational approaches, acting both as complements (Cao & Lumineau, 2015).

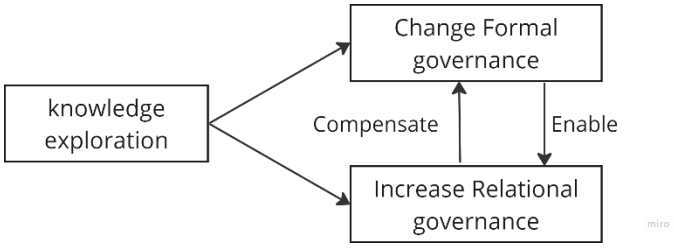


Figure 20: Perturbation 1. Knowledge exploration and complementarity between relational and formal governance

Bridging different knowledge domains to generate a cohesive output is a demanding task that necessitates considerable time, motivation, and effort to establish a common ground where both disciplines can converge (Malherbe, 2022). In this challenging process of knowledge co-creation, learning has emerged as a moderator between equivocality issues and governance approaches. The main challenge faced by both teams was equivocality, where the same information held different meanings for each team. This triggered a learning process where the teams had to understand each other's knowledge needs to provide a solution that satisfied both requirements. This learning process was characterized as double-loop learning, as it helped to challenge the knowledge foundations of each team (Argyris & Schön, 1996).

> *"You would realize that no matter how much you explained your needs, the other person wouldn't understand. It took us a year for them to understand our need, and we had to repeat it many times and vice versa. And then comes the day when they say, "Now I understand what input you needed."* WP5 Project team member – Group 6.

Exploratory search strategies and bridging ties facilitated a deeper knowledge exploration process that resulted in several joint learning outputs (joint articles) (Bäck & Kohtamäki, 2016). The learning processes have been evident not only to manage equivocality but also, to reframe governance approaches. Changing the formal agreement by including a third party and exchanging resources to bridge knowledge gaps (relational governance) required learning processes (McClory et al., 2017).

According to Argyris and Schön (1996) and their Organizational learning perspective, a generative learning (double loop learning) was evidenced in this case, as the partners needed to reframe their own existing knowledge (regarding what geometry means) to overcome perturbations. Additionally, they also had to reframe the governance approaches applied into the project, adapting contractual agreements and increasing the dependency on relational approaches. As a result, once the teams reached mutual understanding, the equivocality levels were reduced, and that enabled the partners to develop joint outputs as the result of the joint collaboration (Bäck & Kohtamäki, 2016).

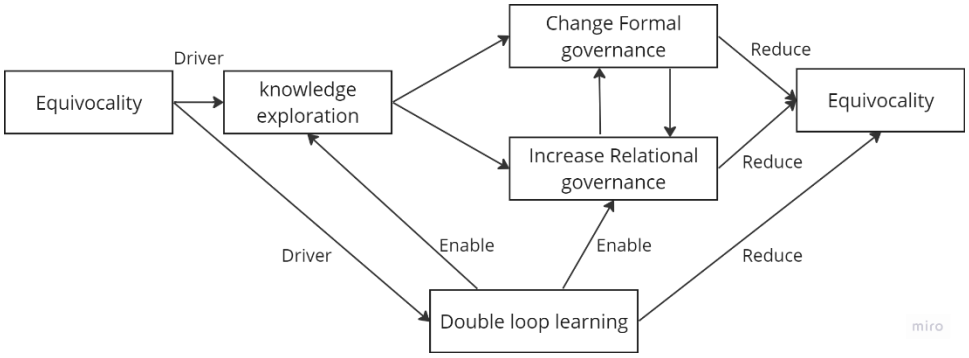


Figure 21. Perturbation 1. Moderating role of organizational learning with equivocality and governance

"*Developing the control architecture has been a steep learning process: researchers with expertise mainly in voice have needed to develop new skills in tools and techniques that interface to three very different domains".* Executive report (third year M36)

"*But being a cross-disciplinary project, the main learning activities and learning outcomes was that the partners started to understand the other fields, the complexities of the other fields, the problems of the other fields and understand what difficulties there are in other fields. So that's a very, very important learning outcome*" WP7 Leader

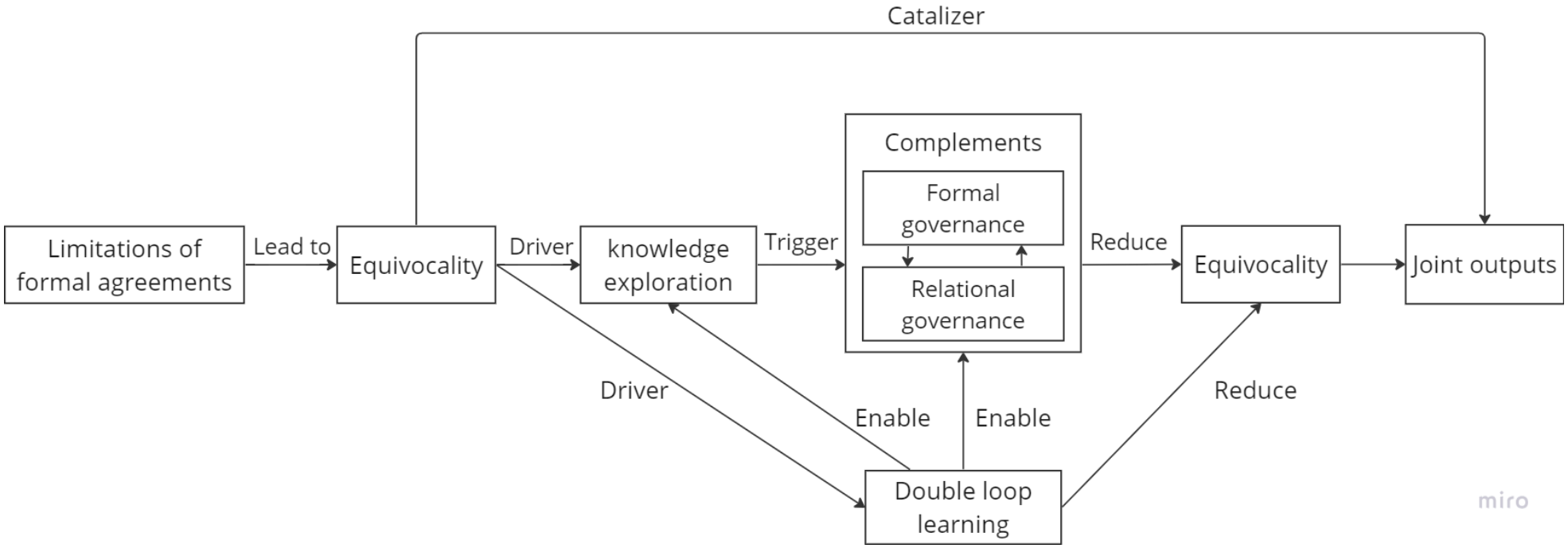


Figure 22: Perturbation 1. Mutual and dynamic interrelationships between equivocality, governance and organizational learning.

12.1.2 Characterization of generative behaviors to overcome perturbations.

During the first perturbation the system was characterized by attention, dialogue and inquiry. During the annual meeting, a partner who was not involved in the work package suggested that a third organization (not involved in the project) could provide the required geometries, the Canadian team. This can be viewed as an instance of attention being directed towards seeking solutions beyond the boundaries of the project. Their willingness to solve scientific problems allowed them to find solutions inside or outside the project and to quickly adopt contingency actions (exchanging resources and involving external partners). The partner responsible for WP7 demonstrated an open-minded attitude by not reacting negatively or with reluctance to the suggestion of involving a third organization that might affect its interests. Instead, they embraced the idea and started collaborating with the new partner to solve their own scientific problem.

> "*During that session, somebody was googling and found that a Canadian group had already made the nice round meshes that Group 6 had been asking for. Which was embarrassing to the people of GROUP 1*" Project coordinator
>
> *"If both parties are willing to cooperate, they will overcome these misunderstandings easily and that is really nurturing".* Scientific coordinator.

According to Chiva *et* al. (2010) *"Attention arises spontaneously when the learner is surrounded by an atmosphere of wellbeing, when he or she feels secure and at ease"*. Despite the delay in delivering geometries by GROUP 1, the rest of the partners provided support and helped them to find alternative solutions. The communication between partners was based on constructive dialogue rather than heated discussions, which allowed for the emergence of innovative contingency solutions.

> "*People were a little bit -you are not delivering what you should do, this is not useful- . But then once we got down to well, -how can we solve this problem? - And it was solved in a very constructive way, and it led to a very close collaboration for several years and resulting in several different high-profile publications. So, the outcome was very successful".* WP7 leader.

Inquiry also characterized the system's behaviour, as the partners dedicated time and resources to questioning and revaluating their existing knowledge in order to comprehend each other's needs and knowledge foundation more effectively. At the end of the perturbation, the partners were able to develop a mutual understanding and as a result, joint outputs were obtained.

The relationships among equivocality, governance, and organizational learning were complex and nonlinear during the perturbation. According to the framework presented in the literature, during the

first perturbation, the system followed a generative pattern. The limitations of formal governance worsened the equivocality issues between partners (Frishammar et al., 2011). However, their determination to solve the problem and openness to seeking solutions from inside/ outside the project (knowledge exploration) enabled them to manage equivocality and successfully develop the necessary geometries (Eriksson et al., 2016). The utilization of relational governance, facilitated by resource exchange, effectively bridged scientific gaps within the project (Morandi, 2013). Additionally, formal governance was modified to formally involve a third party in the project, which compensated for its limitations and helped to adapt it to unexpected situations (Cao & Lumineau, 2015). This circular relationship of "enabler/compensator" of governance approaches allowed the team to overcome equivocality issues and successfully bridge scientific gaps (Benítez-Ávila et al., 2018). Organizational learning acted as a moderator, allowing the teams to reframe existing knowledge and explore solutions to overcome equivocality issues (Marcandella & Guèye, 2018). Joint learning was observed throughout the case, facilitated by relational practices, trust, and a shared motivation among partners to collaborate and find solutions together (Bäck & Kohtamäki, 2016). As a result, the partners were able to overcome the perturbation and return to stability.

12.1.3 Project results´ implications

Once the project returned to stability, the collaborative capacity between the partners involved in the perturbation improved (as an outcome), resulting in an increased number of joint articles (9 conferences and top journals). However, the time and cost allocated to this work package exceeded the initial plan, mainly due to the time and resources invested in overcoming the perturbation.

From an efficiency perspective, the project went beyond the initially allocated time and cost for this work package, while successfully maintaining the intended scope of tasks. However, in terms of value, the outcome of this collaboration holds significant importance within the scientific community. It serves as a valuable demonstration of how two distinct scientific fields can come together to create a new body of knowledge, specifically at the intersection of biomechanics and acoustics.

11.2 Perturbation 2. Complex adaptive system.

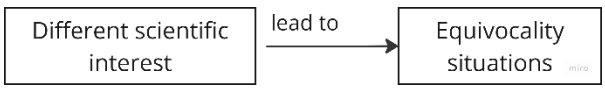
12.2.1 Subsystem´s behaviors and interrelationships.

During the third year, Group 3 and Group 7 had to begin integrating both sets of codes that were developed separately using different methodological approaches and platforms. However, there were many technical issues that prevented a quick and seamless transition from one platform to the other, and different scientific perspectives on how to proceed.

> "*There were two codes. We have the code made by Group 7 and the one made by Group 3. There were not easily exchangeable*" WP5 team member.

These issues increased tensions between the partners due to differing opinions on how to move forward. Equivocality issues did not arise because each partner came from a different scientific field. On the contrary, they were able to quickly understand each other as both teams belonged to the simulation field. Equivocality issues were instead caused by diverse scientific interests in the project, rather than differing backgrounds. These differing interests led to different implications and, consequently, different results.

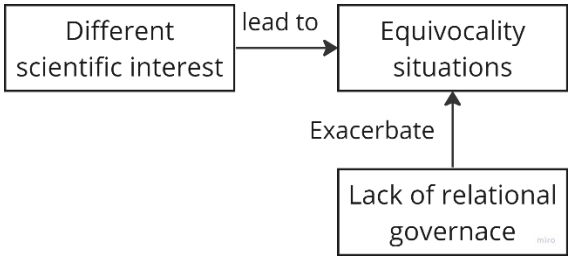
> "*You know, the different groups that work together here, they have maybe different thoughts and different schools of thought in their respective scientific field and different convictions and so on. Regarding how to solve a problem, it turned out to be the most challenging thing because it took so much time to simply agree on how to unify it in the first place*" WP3 team member - Group 4.
>
> "*During the meetings, we (Group 3 & 7) reached agreements very easily because we shared the same language and understood each other well. We were aware of each other's needs before, and agreements were easily reached. I believe they had the experience and the capability, but I think there was a slight failure in their involvement. They were much less involved than us in the project and at the end, the level of maturity of what we had was very different compared to what they had. Integrating these into a single platform was almost impossible".* WP4 team member – Group 7.
>
> *"Their interest didn't come from solving the problem, but because they knew how to create some codes, and they only wanted for another application of their existing codes ´It could be useful for airplanes, for the human heart, and now also for the voice.' However, the problem itself didn't generate enough interest for them"... "the exploration of how the voice works, that scientific curiosity wasn't so present in that group".* WP5 team member - Group 6



The formal agreement provided specific descriptions of the roles and responsibilities within WP4. However, there was a lack of relational governance in the coupling between GROUP 3 and 7, such as face-to-face meetings, supervision or resource exchanges throughout the project lifecycle. This absence hindered the development of closer relationships and trust between the two groups involved in the unification.

> *"I should have been more of a pain in the neck for them at the beginning until I was satisfied that they really were working together, converging and not just working in parallel right" (…) "I should have gone and visited them and say, OK, what are you doing? Is this working toward the common goal?* " Project coordinator.

Two simulation codes evolved separately, and as the project progressed, the inertia to change increased, while relational governance failed to align partners expectations during the project lifecycle. Relational governance did not compensate for the limitations of formal governance by helping to convert resource allocation into partner contributions. The lack of relational governance allowed to increase the hidden tensions and mistrust between partners and exacerbated equivocality situations during the perturbation (Knudsen & Srikanth, 2014).



The mistrust generated by the lack of relational interactions between them exacerbated these viewpoints, fortifying their respective stances (Knudsen & Srikanth, 2014). Neither partner demonstrated a willingness to surrender their position, and a collective agreement between them remained merely impossible to reach. These differences in perspectives about how to proceed rather than pushing partners to explore solutions, hindering the process of knowledge exploration, increasing the reluctance of each partner to explore a solution outside to their knowledge boundaries (Knudsen & Srikanth, 2014).

> *I think there was one annual project meeting, so where the waves soon became a bit high when this friction between the two modelling teams became clear between Group 7 and Group 3*" Project coordinator

> *"My impression was that they pretty much -Sort of- stuck to their own ideas and they worked on the road that they were comfortable with*" Project coordinator.

During the unification meeting, neither team was willing to give up, resulting in a conflict of interests. The coordinating team ultimately determined that the most viable course of action was a compromised solution, whereby each team would persist in developing codes in their own platform. This resulted in the primary solution fragmenting into two integrated approaches, consequently reducing the project's objectives and scope: understating and multifunctionality (Wied et al., 2020).

Each partner maintained their own scientific approach and platform to continue working in the project.

> "*I believe that in the end, the coordinators proposed a solution. Were there different options? Were there any alternatives? No. So, we went ahead with this based on authority. A compromise solution was sought that would be comfortable for all parties involved and would justify the project to some extent. It may not have been exactly as initially desired, but at least to a certain extent*" WP5 Team member – Group 6.

The choice to pursue a compromised solution was made through authority rather than collective agreement, and formal governance emerged as the mechanism that allowed both teams to proceed, albeit at the expense of the project's original goal. This formal governance, manifested in the coordinators' authoritative decision (as opposed to a collective agreement), kept the project in motion (Gil & Pinto, 2018). This decision led each partner to independently work on their simulation code, concentrating on exploiting their existing knowledge to offer a partially unified solution (Eriksson et al., 2016).

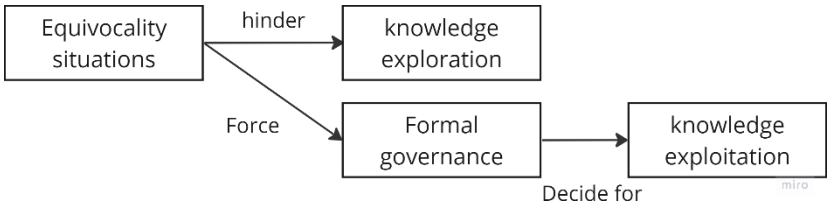


Figure 23: Perturbation 2. Implications of equivocality into knowledge exploration and exploitation

There was limited complementarity between relational and formal governance, between the blueprint produced by the contracts (formal governance) and the compensation effect enabled by relational interactions (relational governance) (Cao & Lumineau, 2015). Formal governance defined the blueprint for working, but relational approaches did not contribute enough to convert initial partner motivation to real partner´s contribution, by aligning their expectations. During the perturbation, there was not an increase in the dependency of relational exchanges or interactions when dealing with disruptions. Instead, formal governance emerged as the primary mechanism for resolving disputes, highlighting that both approaches did not complement each other's limitations; instead, they functioned as substitutes, either/or (Benítez-Ávila et al., 2018).

Different scientific interests coexisted in the project, leading to situations of equivocality, that have been solved by authority, pushing the partners to exploit their own knowledge (Eriksson et al., 2016). After the decision, each partner continued working on their own task, reducing the level of collaboration and relational interactions.

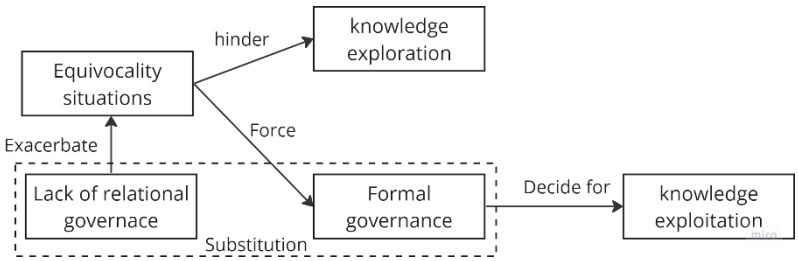


Figure 24. Perturbation 2. Implications of governance in the process of overcoming perturbations

The unification process also involved learning, but this was primarily focused on operational tasks, such as parameterizing the solution from one platform to the other. The partners were more focused on exploiting their own existing capabilities, resulting in limited joint learning (Bäck & Kohtamäki, 2016). As a result, the learning that did occur was primarily incremental and operational for each partner, considered as single loop learning (Argyris & Schön, 1996).

> "*At the end we did a good progress. We (Group 7) had to develop a partial solution with some parametrization to allow them to integrate in their platform. And then, they received our input and parametrized in their framework to run the final simulation. The learning was a matter of parametrization, as we could not reach an agreement about to use a single and unified platform. At the end, there were two codes and we had to parametrize inputs and outputs to run a single simulation, that was a clear reduction in the initial project objectives".* WP4 Project team member (Group 7).

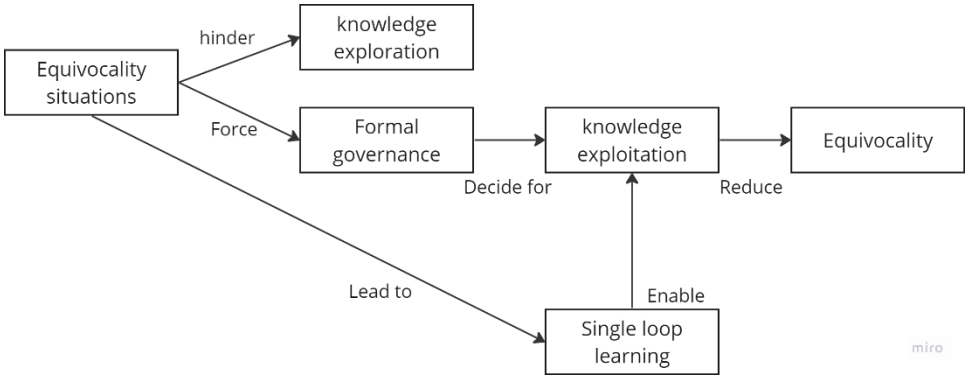


Figure 25: Perturbation 2: Moderating role of organizational learning into the process of overcoming perturbations

There was an absence of inquiry into the underlying knowledge assumptions and methodologies held by each partner. The endeavour taken assumed the character of incremental and individual learning (Chiva et al., 2014), as each partner chose to draw upon their existing knowledge bases rather than venturing into the collective exploration of alternative approaches (Solís-Molina et al., 2021). However, the decision exercised by the coordinators, leveraging their contractual authority, proved instrumental in overcoming the disruption. This decision compelled the partners to leverage their

existing knowledge, thereby mitigating the negative effects of equivocality, as they partners did not have to continue discussing about the platform and not even about relevant project´s decisions (Eriksson et al., 2016). Ultimately, the output of the disruption diverged from the initial intention of yielding a unified solution. Instead, it represented two partially integrated solutions, each constituting an independent and incremental advancement in knowledge for the respective partners.

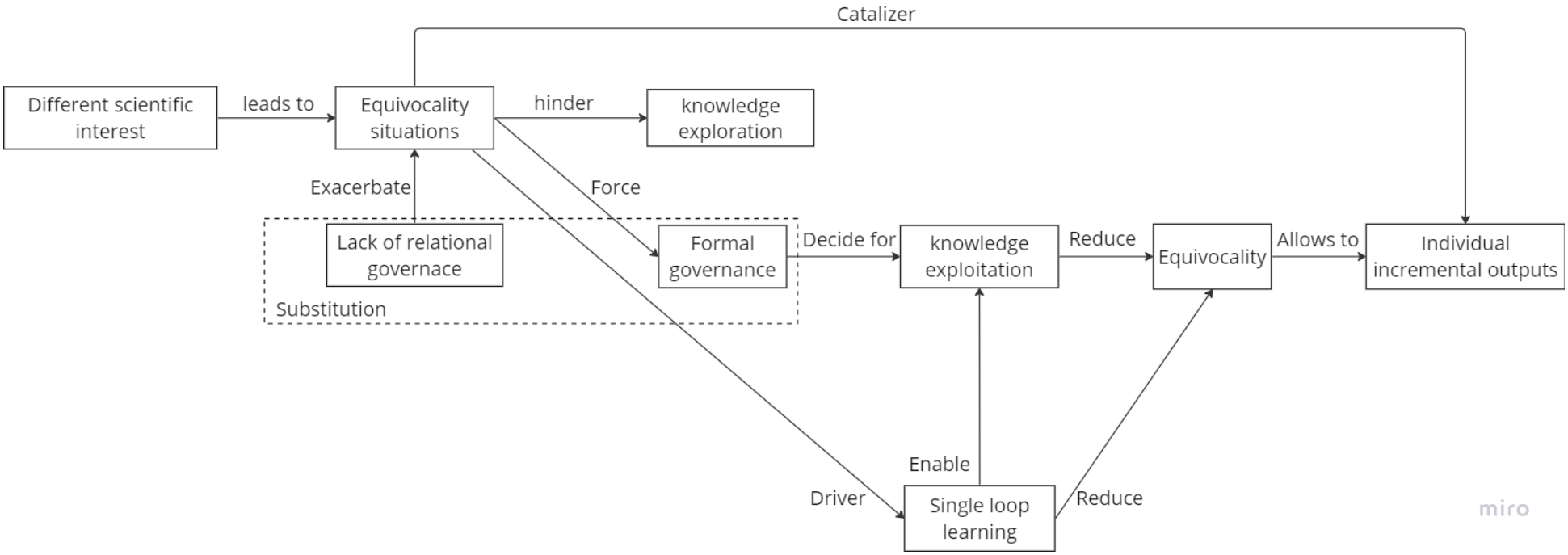


Figure 26: Perturbation 2. Mutual and dynamic interrelationships between equivocality, governance and organizational learning.

12.2.2 Characterization of adaptive behaviours to overcome perturbations.

The system during the second perturbation was characterized by discussion, concentration and improvement. During the unification meeting, both parties were reluctant to accept each other's proposals. They were primarily focused on advocating for their own perspectives and did not consider the other party's viewpoint. This high level of reluctance to accept the other's proposals was further exacerbated by the strong personal postures held by both parties, which hindered fruitful possibilities of reaching a collective agreement. As a result, the dialectic was characterized by discussion rather than a dialogue, where both parties failed to engage in a meaningful exchange of ideas.

> *“They didn't say, "No, we don't want to do it like that", but they formulated it in a way like "Oh no, it's not possible to make sure we did in the realistic framework". And I thought it should actually be two of them"*. WP3 team member.

The negotiation process was primarily focused on winning the discussion rather than reaching a mutually beneficial agreement. This approach created an argumentative atmosphere where the main goal was to identify weaknesses in the opposing party's argument. The process of argument and counterargument resulted in a narrow focus, forcing the mind to concentrate on a single point instead of seeing the bigger picture, being this a characterization of concentration.

> "*We can do this ourselves in a simplified way, but something that is a finished product and has a more recognizable form as what should be a deliverable for the European Commission. However, they refused and stated that it was necessary to use their computational platform, as that was what had been proposed from the beginning and truly that was the intention. Nevertheless, they also didn't offer any capacity to find another solution to this situation.*" WP4 Project team member.

The compromise solution proposed by the coordinators was that each team would work on their own simulation code. Although it was a significant step forward, it was viewed more as an improvement of the state of the art, rather than an innovative solution as originally proposed in the plan. This was because the knowledge creation activities in this reaction primarily involved exploiting existing knowledge rather than exploring new alternatives that combines both research schools. The exploitative search strategy relied on a replication logic where members drew on familiar and accumulated knowledge to develop innovations. This approach is generally faster and less resource-intensive than exploration-based strategies. This represents a characterization of improvement rather than inquiry.

> *"Their interest was not in solving the problem, but rather in creating some codes (..). The actual problem itself did not generate enough interest for them to explore how the voice works. That scientific curiosity was not as present within that group (3)"* WP5 Team member. - Group 6.

To summarize, in the second perturbation, equivocality, governance, and organizational learning acted as a complex system but with different behaviour compared to the first case, characterized by adaptation. The different scientific interest and schools of knowledge of the partners involved in the perturbation, led to situations of equivocality at the end of the project. The absence of relational governance during the project lifecycle, created a context of mistrust among partners, that exacerbated the negative implications of equivocality, once it emerged. Towards the end of the project, equivocality issues arose due to the diversity of interests which were perceived as the main barrier to achieving mutual understanding (Frishammar et al., 2011), hindering the process of knowledge exploration. Formal governance, through the leverage of formal authority, contributed to reduce the negative effects of equivocality, and a compromise solution was imposed by the coordination team to satisfy all parties and reduce tensions (Wied et al., 2020). This solution represented an exploitation of the existent knowledge of each partner (Eriksson et al., 2016) and enabled the project to continue progressing, mitigating equivocality. However, formal and relational governance acted as substitutes (either / or) in this case. The interplay between equivocality and governance in this reciprocal cycle was moderated by the organizational learning process, characterized by a single loop. This process entailed parameterizing the system to facilitate the integration of both independent solutions, resulting in a swift integration of one solution into the other (Benítez-Ávila et al., 2018). This system configuration enabled also the project to be resilient, even though there are different performance effects associated in this case

12.2.3 Project results´ implications.

The actions taken by coordinators and partners enabled them to overcome the perturbation and return to stability (Wied et al., 2020). Once the project returned to stability, the collaborative capacity between the partners involved in the perturbation decreased, and it was even lower than during the project.

> *"Once the project solved the issue of unification, the level of collaboration between both organizations were even lower than at the beginning of the project".* WP8 leader.

In terms of efficiency, the partners were able to develop a solution in time and, with the resources allocated for WP4. However, this was enabled by a reduction in the scope of the solution (Wied et al., 2020). It is important to mention that European projects face high pressure to meet fixed and inflexible

time deadlines, forcing the partners to find solutions that enable them to meet challenging time constraints (Klessova et al., 2022).

On the other hand, under the perspective of value, the output delivered after the perturbation represented a novel step forward for each organization. However, these outputs are associated with individual rather than joint outputs (articles). The partners were able to continue exploiting their existent knowledge after the perturbation, what is associated with an incremental innovation (Kobarg, Stumpf-Wollersheim, & Welpe, 2019). The second aspect to consider is the negative implications in terms of collaborative capacity, as the level of collaboration between partners decreased after the perturbation.

12.3 Case analysis conclusion.

In summary, as it is described in Table 10, the empirical cases made evident different reactions to perturbations. In the first case, the overall system behaved following a generative pattern characterized by attention, inquiry and dialogue. In the second case, the overall system behaved following an adaptive pattern of reaction, characterized by concentration, discussion and improvement. In this following table is represented each one of the systems' behaviours.

Subsystem	Perturbation 1: System characterization	Perturbation 2: System characterization.
Equivocality	- Driver for expansive and higher-level learning. - Driver for knowledge exploration activities. - Driven by diversity of knowledge backgrounds.	- Barrier for higher and deeper learning. - Barrier for knowledge exploration activities, prompting knowledge exploitation activities. - Driven by diversity of interest and scientific schools.
Governance	- Complementarity between formal governance and relational governance, acting in the form of enabler/compensator. - Increased dependency on relational governance to bridge scientific gaps.	- Supplementary between formal and relational governance (acting as either /or). - Increased dependency on formal governance (formal authority) to bridge interest´s gaps.
Organizational learning	- Double loop learning (Joint learning). - Enabling joint knowledge exploration - Moderator between equivocality and governance at exploration activities.	- Single loop learning (incremental individual learning). - Enabling individual knowledge exploitation. - Moderator between equivocality and governance at exploitation activities

System´s behaviours	Generative system / transcendence: 1. Attention 2. Dialogue 3. Inquiry	Adaptive system /adaptiveness. 1. Concentration 2. Discussion 3. Improvement
Results	Output: Increased cost, time and maintaining scope. Outcome: - increased collaborative capacity. - Joint outputs	Outputs: Reduced scope, maintaining time and cost. Outcome: - reduced collaborative capacity (working as islands) - Individual outputs.

Table 10: Summary of cross-case analysis.

13. Discussion.

13.1 Introduction

In projects embedded in context of high uncertainty and complexity, such as the case of collaborative projects, their success highly relies on their ability to overcome perturbations (Naderpajouh et al., 2020). This research addresses this problem by studying how a successful project (LOCUTIOS) was able to overcome two instances of perturbations and to still deliver outputs and outcomes. The research framework proposes that the evolving, mutual and non-lineal relationships between equivocality, governance and organizational learning contribute to explaining how a project is able to overcome perturbations.

The literature is extensive in giving different explanations and interpretations of the lineal relationships (simple cause-effect) between the three constructs (Eriksson et al., 2016; Marcandella & Guèye, 2018; Solís-molina et al., 2020). However, it was hypothesized in the literature review, and it was confirmed in the cross-case analysis, that the three constructs are highly interconnected during perturbations. The result of the system was the result of the evolutionary processes made of feedback loops between them, each one influenced and has been influenced by the behaviours of the others. This comprehensive perspective is aligned with Majchrzak *et* al. (2015) by considering overcoming perturbations as a dynamic phenomenon, better explained by non-linearity and mutual causality between the three constructs.

13.2 Proposition 1: Complex interdependencies in the process of overcoming perturbations.

We have analysis two instances of perturbations, being the perturbation the unit of analysis. In both cases, unpredictable situations originated by the inherent scientific uncertainty of collaborative research projects led the project to situations that might be considered as limited instability or the edge of chaos (Chiva et al., 2010). The diversity of partner´s backgrounds and interests creates a rich pool of knowledge sources, perspectives and ideas, but also poses a significant managerial challenge to deal with (vom Brocke & Lippe, 2015). The lack of accuracy in formal agreements, in the first case, and the lack of relational approaches, in the second one, created certain conditions -that during perturbations- exacerbated the inherent diversity of interpretations (equivocality) and increased the tensions among partners. In both cases, misunderstandings between partners, originated by the diversity of backgrounds and interests, generated situations that might be considered as the edge of chaos, according to the complexity theory (Chiva et al., 2010). Not resolving these situations of equivocality would have resulted in a severe setback in the project's progress.

Governance adaptation played a role in the process of overcoming perturbations and managing equivocality (Yang et al., 2022). Adapting governance by modifying objectives, strategies, resources

and methodologies enabled the project to tackle unforeseen issues (Kujala, Aaltonen, Gotcheva, & Lahdenperä, 2021). Increasing the dependency on relational interactions contributed to develop trust between partners, creating a common understanding and mitigating conflicting situations (Davenport et al., 1998). Increasing the dependency on formal authority also contributed to reduce conflicts and enabled the project to continue working (Gil & Pinto, 2018). In both cases, the adaptation of governance enabled the project to overcome both perturbations. However, according to the literature, in one situation, governance approaches acted as complements (enabler/ compensator) and as substitutes (either / or) in the other case (Cao & Lumineau, 2015). This makes evident that there is not a unique manner to adapt governance to face and overcome unforeseen threats.

In both cases, the absence of or the changes in governance exacerbated or mitigated the effects of equivocality. In the first case, equivocality situations triggered as a process of knowledge exploration, that was enabled by the adaptation of formal and relational governance approaches, following complementary effects (Cao & Lumineau, 2015). In the second case, equivocality situations hindered a process of knowledge exploration, forcing formal governance to focus the partners on knowledge exploitation activities (Solís-molina et al., 2020). It has been shown in both cases, how both constructs evolved during the process of overcoming perturbations, following loops of mutual causality (Majchrzak et al., 2015).

In both cases, the learning behaviours enabled partners to explore novel alternatives or to exploit existent knowledge in order to overcome the perturbation (Eriksson et al., 2016). Additionally, it was found that equivocality situations were the trigger for deeper and higher-level joint learning (Marcandella & Guèye, 2018) or faster and superficial individual learning (Eriksson et al., 2016). In this sense, organizational learning played a moderating role in the process of overcoming perturbation. The learning behaviours employed by the project teams, considered as generative and adaptive respectively (Senge, 1990) have influenced the evolution of governance, equivocality and their effects.

During perturbations, this research work is able to propose that equivocality, governance and organizational learning constitute a complex system, whose relationships are better explained by feedback loops, mutual causality and non-linearity. Consequently, the result of the system is no longer the result of the sum of its components (Simon, 1996). Contrarily, it has been proven that each one affects and is affected by the behaviour of the others, and the result of the system, is the result of the evolving, dynamic, mutual causality and non-lineal relationship between them. In this vein, a first proposition of this research is formulated as follows:

Proposition 1: During perturbations, equivocality, governance and organizational learning constitute a complex system made of mutual causality and non-linearity on the relationships.

Furthermore, the patterns of reactions have exhibited different behaviours, highlighting the relevance of the research approach that elucidates the process of overcoming disruptions through the application of systemic perspectives. Systems perspectives provide a more comprehensive view of a phenomenon, and complex systems are useful to capture dynamic and non-lineal relationship between components. Derived from the research, it has been found that there are (at least) two manners of overcoming perturbations, analysing the interplay between equivocality, governance and learning, that might follow either generative or adaptive patterns of evolution. By applying complex generative and adaptive systems (Chiva et al. 2010), the researchers were able to study different behaviours for each construct, possible connections between them and different system´s results in terms of efficiency and value perspectives.

13.3 Proposition 2: Generative resilience.

During the first perturbation, equivocality issues -related to vocal tract geometries- triggered a process of higher-level joint learning (Marcandella & Guèye, 2018). The lack of clear specification regarding the degree of data accuracy of the geometries in the formal agreement exacerbated the different interpretations among partners about the same information. Following a year without reaching a shared understanding, situations of equivocality worsened, tensions among partners escalated, and the project even received a warning signal from the sponsor. Equivocality situations were the symptoms of the increased tensions between partners for not being able to develop a mutual understanding about how to develop the geometries. This situation might be considered as the edge of chaos, triggering a process of change (Gell-Mann, 1994).

In response to this, the teams went beyond their usual areas of expertise and embarked on a journey of exploring new knowledge and solutions from inside and outside the project boundaries (Eriksson et al., 2016). This exploration was aimed to find alternative and novel solutions that would enable them to overcome the obstacle and continue progressing in the project. In this sense, equivocality triggered a process of knowledge exploration (Eriksson et al., 2016).

Relational governance, through exchange resources (researchers), acted as a bridging tie (Tiwana, 2008) that enabled both different disciplines to talk the same language and develop a common understanding. Additionally, this exchange contributed to increasing the interactions among partners and further trust among each other, improving collaboration quality (Davenport et al., 1998). Formal governance (contractual agreements) has been also adapted to allow an external partner to work within the consortium of partners to deliver the required geometries that the existent teams were not able to deliver. In this sense, relational governance compensated for the limitations of the initial formal governance, and the latter was also adapted to meet the changing requirements. Formal and

relational governance acted as complements, following iterative cycles of enabler/compensator (Benítez-Ávila et al., 2018). Such behaviour in the governance of the project was determinant to overcome the perturbation and to reduce equivocality levels. An increase on the dependency of relational approaches improved partner´s trust and enabled them to bridge their scientific gaps and develop common understanding (Davenport et al., 1998). The adaptation of formal governance to include new partners contributed also to filling the knowledge gap. Summarizing, the complementarity between both contributed to reduce equivocality levels, to develop joint outputs enriched by different scientific disciplines and finally overcoming the perturbation.

The organizational learning in this case was characterized as a double loop learning (Argyris, 1976). This occurs when the team challenges and reconsiders the underlying assumptions about a concept, problem or procedure (Argyris & Schön, 1996). In this case, learning was evident when the partners reframed their own knowledge foundations to develop a common understanding (Marcandella & Guèye, 2018). This learning process is deeper, as each member needs to understand the requirements of the other´s and to questions its own knowledge assumptions (Davenport et al., 1996). The learning processes were evident not just for gaining and advancing new knowledge, but also in the adjustment of governance methods to meet changing project requirements (McClory et al., 2017). The teams had to learn how to collaborate with the new partner and adapt to collaborating with a researcher in the labs of the other team.

In this context, double loop learning (Argyris & Schön, 1996) recognized as a deeper learning process, emerged as the primary learning behaviour among partners. This learning behaviour correlates positively with activities involving knowledge exploration (March, 1991). The partners' willingness to propose diverse alternatives when faced with unexpected knowledge gaps has enabled them to invest time and resources in exploring solutions and enhancing their relational activities. The increase in relational exchanges has also bolstered trust among partners, resulting in a positive influence on the adaptation of formal governance structures to address unforeseen issues (Morandi, 2013). Double loop learning not only fostered knowledge exploration but also facilitated the adjustment of both relational and formal governance mechanisms (McClory et al., 2017). This generative behaviour -generative learning-, has played a pivotal role in generating new knowledge and methodologies, effectively overcoming equivocality issues. It emphasizes the prioritization of producing valuable joint outcomes over individual outputs (Malherbe, 2022).

After overcoming the perturbation, the collaborative capacity of teams involved increased and it is reflected by continued collaborations among partners after the project, and the joint outputs

developed together. Since in this case a generative learning behaviour has been identified, the system's configuration is referred as generative resilience.

Proposition 2: Generative resilience is characterized by double (generative) loop learning, complementarity between relational and formal governance approaches and equivocality acting as a driver for knowledge exploration.

13.4 Proposition 3. Adaptive resilience

During the second perturbation, the system's behaviour was different, even though misunderstandings were also the reasons that escalated tensions between partners and led to a situation that might be considered as the edge of chaos. In this case, the reasons that originated equivocality situations were the diversity of interests and knowledge schools between partners who belonged to the same knowledge domain of simulations. The lack of trust among partners, usually associated with a lack of relational governance (Cao & Lumineau, 2015) did not contribute to align partner expectations, conversely, this exacerbated their inherent differences. Individual interests were prevailing over a common interest in the unification process (Malherbe, 2022). Consequently, both teams encountered difficulties in integrating their separate developments into a unified solution, as each team had their own distinct understanding about how to proceed. In this sense, equivocality situations acted as a barrier for knowledge exploration (Frishammar et al., 2011), exacerbating tensions among partners and ultimately restraining resources.

In response to this perturbation, the coordination team had to make the decision to adopt a compromised solution that satisfied both partners, due to their inability to reach a common agreement by themselves. Instead of exploring for novel solutions, the teams involved focused on trying to exploit their own knowledge and keep closer to their own field (Solís-molina et al., 2020). After the decision made by coordinators, equivocality issues were also reduced, since the partners no longer needed to maintain intensive collaboration. Instead, they focused on their individual tasks with minimal interaction between each other. Equivocality situations prompting a process of knowledge exploitation.

Equivocality issues were reduced mainly by the implementation of formal governance (reflected by formal authority on decision-making process) instead of reaching a collective resolution among the involved parties (Gil & Pinto, 2018). Formal governance provided the blueprint of working, but relational governance did not contribute enough to align a diversity of interests, to enhance trust between partners and to convert initial motivations into real contributions (Benítez-Ávila et al., 2018). Formal and relational governance acted as substitutes during the second perturbation (Cao & Lumineau, 2015). It is known that the increasing dependency on contractual governance is a signal of

a lack of trust and harms the development of relational governance (Cao & Lumineau, 2015). The limited relational interactions between teams hindered the process of developing trust among them and force coordinators to make decision based on their formal authority, being this evidence on the substitute effects between both formal and relational governance. Then, it is known that contractual governance is more effective when it is associated with knowledge exploitation rather than exploration (Solís-molina et al., 2020). This case also makes this evident, as the teams focused on exploiting separately what they had done until the unification meeting to overcome the tensions and reduce equivocality.

Organizational learning also played a moderator role between equivocality and governance during the second perturbation (Argyris & Schön, 1996). Learning processes enabled both teams to provide a solution that fits with both (opposing) needs. The approach taken to integrate the two solutions was mainly focused on parametrization and adaptation of one solution into the other one, resulting in superficial learning characterized as a single loop or adaptive learning (Argyris & Schön, 1996; Senge, 1990). No inquiry processes were found to explore the knowledge foundations and practices of each team, and the resulting output represented an incremental and individual learning of the existing knowledge of each partner (Chiva et al., 2014). The actions taken to overcome the perturbation ultimately resulted in a satisfactory output, but it required a reduction in the scope and objectives.

Even though the teams were able to overcome the perturbation and continue with the project, their collaborative capacity was even lower than before the perturbation (Klessova et al., 2020). In this case, their behaviours were completely different compared to the first one, following a fragmented approach, each team continued working separately (Malherbe, 2022). As adaptive learning has been identified in this case, we refer this system´s configuration as adaptive resilience.

Proposition 3: Adaptive resilience is characterized by single-loop learning, substitution effects between relational and formal governance approaches, and equivocality acting as a barrier for knowledge exploration, promoting knowledge exploitation processes.

13.5 Proposition 4: Characterization of generative resilience.

Overcoming perturbations does not only require the teams to take actions, but it also depends on the behaviour of the participants in response to the potential threats. Different learning behaviours produce different results (Senge, 1990). Generative behaviours (Chiva et al., 2010) enable the system to transcend the status quo and to develop a more reliable system after the perturbation (Bohm, 1980). Adaptive behaviours enable the team to quickly overcome perturbations, but through no changes in the core functions of the systems (Anderson, 1999).

According to complexity theory, complex generative systems (Chiva et al., 2010) described as the ones that are able to transcend when they reach the edge of chaos. These are characterized by attention, dialogue, and inquiry. In the first perturbation, the teams involved were open-minded and flexible on finding solutions outside of their existing knowledge domain by including external partners, changing formal agreements and exchanging technical resources. They did not solely rely on their existing knowledge, but rather explored solutions to fill their knowledge gaps, as a characterization of attention. The process of overcoming the perturbation involved dialogue and inquiry to understand the different perspectives and find a joint solution that would benefit all parties involved. The approach taken in this perturbation represents generative learning, where new knowledge is created through collaboration and exploration (Senge, 1990). The teams' shared motivation and willingness to solve the problem, and their learning behaviour enabled constructive dialogue that bridged knowledge gaps. As a result, the proposed solution represented a significant step forward in the project and allowed the teams to create joint knowledge (Faccin et al., 2019) by reformulating their knowledge foundations, reflecting the characteristics of inquiry.

Generative resilience enables the project to self-transcend when it reaches the edge of chaos (Jantsch, 1980). Self-transcendence involves questioning the underlying assumptions (implicate order) held by partners with regard to their foundational knowledge, strategies, and operational methodologies to develop a more reliable and robust system after perturbations (Bohm, 1980). Self-transcendence enabled the partners to acquire knowledge from other fields as well as adapting managerial strategies to be able to convert knowledge from a variety of sources into a joint and integrated output (Bäck & Kohtamäki, 2016). As a result, self-transcendence enabled the project to return to stability, but with higher levels of robustness and reliability (Chiva et al., 2010), making it evident in a better collaboration quality after the perturbation.

Proposition 4a: Generative resilience is characterized by attention, dialogue and inquiry.

Proposition 4b: Generative resilience is characterized by self-transcendence and associated with a more reliable and robust system after perturbations.

13.6 Proposition 5: Characterization of adaptive resilience.

Complex adaptive systems are characterized by concentration, discussion, and improvement, and they can adapt when they reach the edge of chaos (Anderson, 1999; Chiva et al., 2014). During the second perturbation, the teams involved were focused on identifying weaknesses in each other's solutions during the meetings (concentration), rather than seeking an overarching solution that could encompass both perspectives (Malherbe, 2022). The dialectic was characterized by discussion, as two opposing positions failed to reach agreements on their own. Consequently, the proposed solution

represented the exploitation of existing knowledge, incremental learning (individual learning for each organization), being characterized as an improvement rather than inquiry (Arranz & de Arroyabe, 2008).

Adaptive resilience enables the project to self-organize and adapt when it reaches the edge of chaos. Adaptability enables fast reactions to return to system´s stability without modifying the core assumptions of the system (Anderson, 1999). In adaptive resilience, the partners do not challenge their existing knowledge foundations and their managerial practices (implicate order). Rather, they move around the explicate order, exploiting the knowledge already acquired without questioning its foundations (Chiva et al., 2010). As the learning is made of single loops, incremental outputs are the result of superficial and faster system´s adaptation (McClory et al., 2017). The results are associated with individual knowledge improvements among partners. Consequently, self-adaptation facilitated the project's return to stability, all the while maintaining the system's inherent characteristics. However, this adjustment was linked to a decline in collaboration intensity after the perturbation (Klessova et al., 2020).

Proposition 5a: Adaptive resilience is characterized by concentration, discussion and improvement.

Proposition 5b: Adaptive resilience is characterized by self-adaptation and associated with superficial improvements without inquiring about the core assumptions of the system.

The central focus of this research lies in the research framework proposal, which constitutes the primary contribution of this study. Furthermore, this research introduces novel and empirical contributions to the existing literature pertaining mainly to the concepts of equivocality and project´s success during perturbations. To elaborate, the research delved into the intricate dual-sided implications of equivocality and how the dual paradigms of project success coexist in collaborative projects during perturbations, affecting the project results.

13.7 Proposition 6: The double-edged sword of equivocality in its implications.

Recent literature conceptualizes equivocality as a double-edge sword (Eriksson et al., 2016; Marcandella & Guèye, 2018). As it was explained in part I chapter 2.3, on the one hand, equivocality might act as a driver for knowledge exploration activities and expansive learning (Dodgson, 1993; Marcandella & Guèye, 2018; Mu et al., 2021). On the other hand, equivocality might also act as a barrier for knowledge exploration and integration, restricting the team's capacity to reach agreements and intensify tensions among partners (Burström & Wilson, 2018; Ness, 2009). Each type of implication is linked to different project result´s (Eriksson et al., 2016; Marcandella & Guèye, 2018). However, this specific case study goes beyond that by offering additional empirical insights into the

origins that catalyse each type of equivocality´s implication into the project results. According to the origin of the equivocality situation, it has been identified two system´s configuration, associated with different project results after overcoming perturbations.

During the first perturbation, situations of equivocality arose due to the diversity of knowledge domains, complicating the process of giving a common meaning to the shared information, the vocal tract geometries. Even though the partners were willing to understand each other, their diversity of knowledge domains impeded effective communication (Stevens, 2014). However, due to the partners had a similar interest to solve the problem, two contingency actions were applied: exchanging resources and including external parties. As it was previously explained, these equivocality situations triggered a process of knowledge exploration and joint learning, involving in-depth learning, and governance adaptation. The results of overcoming this perturbation are associated with an improved collaboration among partners and joint knowledge outputs (Bäck & Kohtamäki, 2016). In this sense, equivocality situations triggered change processes associated with positive results, reinforcing one edge of the sword (Eriksson et al., 2016; Marcandella & Guèye, 2018). Despite the broad diversity of knowledge domains that led to increased tensions among partners, the presence of common interests, collective willingness towards the project and double loop learning, significantly influenced the response to perturbations.

During the second perturbations, situations of equivocality arose due to different and incompatible interests into the project between two partners that belonged to the same knowledge domain (Calamel et al., 2011). This issue limited the capacity of partners to reach agreements by themselves and exacerbated equivocality situations, despite of they were able to easily understand each other (in technical aspects) during the meetings. As they were not able to reach a collective agreement, coordination teams forced them to work each one on their own tasks, reducing the collaboration intensity and the scope of the project after the perturbation. In this sense, equivocality situations restrained resources, limited the capacity to reach agreements, impeded knowledge exploration and joint learning, reinforcing the other side of the sword (Frishammar et al., 2011). Despite of the fact that partners were able to easily understand each other due to they shared the same scientific language, they were not able to reach common agreements because they did not share the same scientific interest. In this sense, sharing similar knowledge domains, "*talking the same language*" not necessarily contribute to maintain low levels of equivocality (Klessova et al., 2020). The diversity of interests forced managers to make decisions based on formal authority and their low commitment to collaborate together triggered individual and superficial learning processes. In this sense, the diversity of interests (not backgrounds) conditioned the reaction to perturbation, highlighting the negative effects of equivocality on performance (Frishammar et al., 2011).

The reactions to two instances of perturbations -triggered by equivocality situations- contributed to improve the existing knowledge about the dual implications of equivocality, acting as a double edge sword in interorganizational projects (Brun, 2016; Eriksson et al., 2016; Marcandella & Guèye, 2018). This study provides empirical explanations for these dual effects and explores the factors that gave rise to and influenced the responses to these disturbances. In this sense, we are opening the black box about how and why equivocality affects performance results (Eriksson et al., 2016; Marcandella & Guèye, 2018). Eriksson et al. (2016), found that explorative search mitigates the negative effect of equivocality on project performance. Marcandella & Guèye (2018) found that equivocality might act also as a trigger for deeper and higher level (expansive) learning. Brun (2016) found that different equivocality tolerance levels are associated with exploration phases and exploitation ones. However, there is no research to date (as far as these researcher's current knowledge) that provide empirical evidence of the dual implications of equivocality in project results and what factors influence each one of the implications. In this sense, this research proposes the following propositions as a further explanation of the double-edged phenomenon:

Proposition 6: The sources of equivocality condition the either positive or negative implications of equivocality in performance results.

Proposition 6a: Equivocality originated by the diversity of knowledge domains might drive knowledge exploration and double loop learning if the partners share similar interest into the project.

Proposition 6b: The diversity of partners' interests might give rise to equivocality situations and exacerbate tensions among partners. These limit knowledge exploration activities and restrain resources, irrespective of whether they share the same knowledge domain.

13.8 Proposition 7: Project success implications in the process of overcoming perturbations.

The second aspect to consider is about project "success". This topic has been extensively discussed among researchers in the literature of project management (Padalkar & Gopinath, 2016; H. J. Smyth & Morris, 2007; Söderlund, 2011). Two very different approaches coexist in the literature, such as project success under the perspective of "efficiency" or under the perspective of "value" (P. Daniel & Daniel, 2018; Laursen & Svejvig, 2016). Assessing project success based solely on the efficient development of project outputs is fundamentally different from evaluating it in terms of the value that outcomes bring to the stakeholders. This topic has been addressed in part I, chapter 2.4 and 4.3 and the contribution is further developed next.

Rather than closing the discussion, this research sheds light on how the relationships that exist between the different types of resilience identified and the project success´ perspectives associated

to them (Padalkar & Gopinath, 2016). The discussions between partners about how to proceed, what actions needed to be taken and the implications in terms of results had a different focus in each perturbation. During the first perturbation, it has been identified that the teams involved were focused on seeking for solutions inside or beyond their boundaries to tackle the scientific problem. They were willing to invest more time and resources to be able to deliver what was supposed to deliver, to maintain the scope of the project by creating an output that combines two different disciplines, biomechanics and simulations. Under the perspective of efficiency, overcoming this perturbation did not meet the objectives in terms of time and cost, as the partners invested more resources and delivered the geometries later than was expected. However, in terms of value, the output delivered after the perturbation represented a relevant step forward for the organizations involved, as they were able to develop a joint output that combined two different disciplines (Pargar, 2019). Additionally, they continued collaborating after the project and a new research stream was opened as the combination of both disciplines (Chiesa & Frattini, 2007). In this sense, the results of generative resilience are associated with value perspectives as a manner to measure the success of the results of the perturbation (Laursen & Svejvig, 2016)..

During the second perturbation, the teams involved were focused on keeping closer to their own knowledge domain and to try to find weaknesses in the other´s approaches, prevailing individual rather than collective objectives (Malherbe, 2022). As the project neared its conclusion, discussions focused on devising approaches to achieve the objectives within the constraints of time and cost. Temporal limitations within projects funded by the public sector are generally inflexible and set (Klessova et al., 2020). Exploiting existing knowledge and superficial learning processes are usually faster and less resource´s consuming than exploration activities (March, 1991). The teams were able to provide a partially integrated solution on time, achieving time objectives and investing the resources already allocated to the work package, but reducing the scope of the final solution. Under the perspective of efficiency, the results associated with the second perturbation achieved the time and cost objectives, but at the expenses of the value added by the outcomes (Atkinson, 1999). Adaptive resilience enables a quick return to system stability without challenging the underlying assumptions of the teams involved and enabled by knowledge exploitation. In this context, it has been identified that the outcomes of adaptive resilience are associated to efficiency perspectives, serving as a metric to assess the success of perturbation-related results (P. Daniel & Daniel, 2018).

Rather than closing the discussion about “project success” (Ika & Pinto, 2022), this research makes a contribution to the field by shed light into different resilience behaviours associated with different project success measures. According to the LOCUTIOS case study, when the system was characterized by adaptiveness, a quickly return to stability, the focus of the discussions remains closer to cost and

time perspectives (Atkinson, 1999), without questioning or addressing the value added by the output (P. Daniel & Daniel, 2018). In contrast, when the system exhibits self-transcendence, prompting a re-examination of the fundamental assumptions of the problem and resulting in a more reliable system post-perturbation, the discussions prioritize value perspectives at the expense of time or cost objectives (Pargar et al., 2019). In this sense, different perspectives about success emerge during perturbations and condition how the teams proceed to overcome them (P. Daniel & Daniel, 2018).

P7a: Adaptive resilience is associated with the efficiency paradigm (time/cost) as a measure to evaluate the results of the process of overcoming perturbations.

P7b: Generative resilience is associated with the value paradigm as a measure to evaluate the results of the process of overcoming perturbations.

13. 9 Research framework proposal to understand the process of overcoming perturbations

This research framework proposal is a novel contribution to the literature as it explains two different patterns of reactions to overcome perturbations, originated by the inherent uncertainty of collaborative projects. This research framework represents the summary of the discussion where the propositions are aggregated into a single framework that explains different patterns to achieve resilience. It focusses on three critical aspects of collaborative projects such as equivocality, governance and organizational learning that are interrelated during unstable situations. We propose that these relationships are better explained by mutual causality and non-linearity.

In both cases, equivocality situations in the form of misunderstandings among partners were the symptoms that revealed the increased tensions among them, considered as situation of temporal instability or the edge of chaos. In both cases, these situations forced the organizations to react and adapt or transcend respectively.

In the first case, equivocality acted as a driver for expansive learning and knowledge exploration, enabled by a complementarity between relational and formal approaches and characterized by a double loop learning. None of them might exist by their own, as they are affected by the behaviour of the others and vice versa. This system´s configuration enabled the project to overcome the perturbation by transcending its initial state. The outcomes associated with this behaviour include an enhancement in the quality of collaboration among the involved partners, reflected in joint outputs stemming from the collaboration between two fields, as well as an increase in both the time and cost allocated to this work package. This result represents a characterization of self-transcendence when a system faces a perturbation.

In the second case, equivocality acted as a barrier for knowledge exploration, fostering knowledge exploitation -as the main knowledge search strategy to reduce tensions- and it was better executed by formal governance implications. Formal and relational governance acted as substitutes, either / or and they do not complement each other. Last, as the change implies mostly knowledge exploitation activities, single loop learning is found as the predominant learning approach, leading to individual/ incremental knowledge outputs. This system´s configuration enabled the project to adapt when it faces a perturbation. The outcomes associated with this behaviour encompass a decrease in the collaborative capacity of the involved partners, which is evident in the incremental outputs developed separately after the disturbance. Since this behaviour is more closely related to knowledge exploitation, the cost and time objectives remained unchanged during the perturbation. This result represents a characterization of self-adaptation when a system faces a change situation originated by a perturbation. The research framework proposal is visually summarized in the next Figure 27.

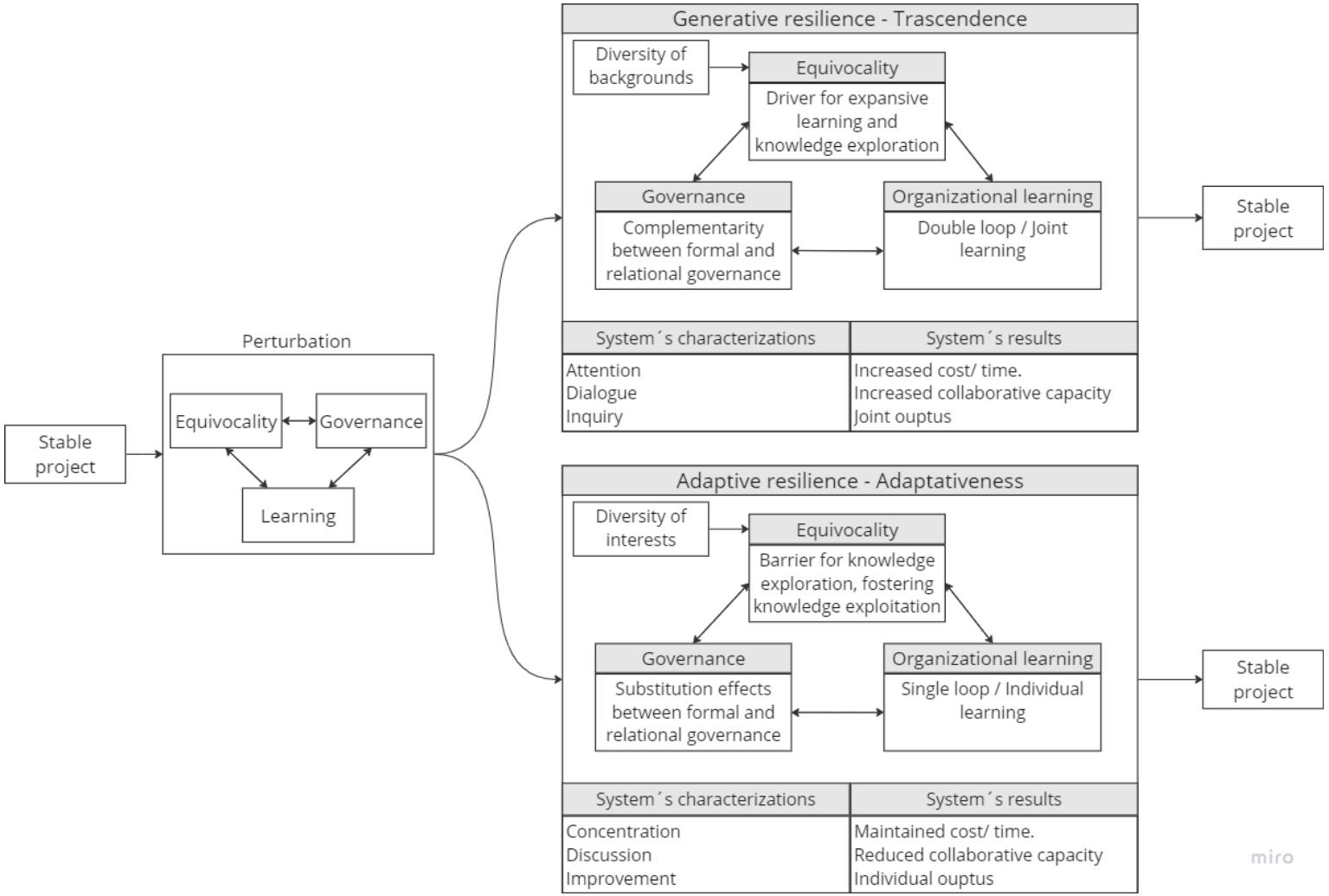


Figure 27: Research framework proposal. Generative and adaptive resilience. A complex-system perspective approach.

14.Conclusion.

14.1 Introduction.

Private companies and public agencies are intensifying their investments in collaborative initiatives to enhance their innovative endeavours. Since the onset of the 21st century, the practice of opening organizational boundaries to access external and scarce resources, knowledge, and expertise has become one of the most prevalent strategies for enhancing innovation processes (West & Bogers, 2014). Despite the growing reliance on collaboration as a mean to drive innovation, a significant number of these projects fall short of meeting the triple constraint objectives or satisfying the stakeholders involved (Fernandes et al., 2021). This research aimed at enhancing the understanding of how projects can achieve success and the factors that either hinder or facilitate it, addressing a pertinent issue in the realm of collaborative projects.

Project success has been one of the most researched topics in the literature of project management with recent calls for papers in top journals (Ika & Pinto, 2022). Two different research streams coexist, evaluating project success according to the efficient or value paradigm (P. Daniel & Daniel, 2018; Padalkar & Gopinath, 2016). This research provided in-depth descriptions about what project success represents in the context of collaborative projects. Recognizing that project success can represent either the efficient development of an output or the valuable delivery of project outcomes to stakeholders, this research focusses on exploring the impact of equivocality and governance on project results, considering both paradigms of success measurement. Equivocality is one of the main challenges of a network of partners characterized by a diverse broad range of interests and backgrounds (Frishammar et al., 2011). Governance approaches represent the managerial efforts conducted by coordinators and partners to achieve project objectives (Pinto, 2014). This study focused on the implications of equivocality and governance into project results and how these interplays together.

The first part of this work has focused on exploring the relationship between equivocality and governance, and their implications on project results and its success measures. An initial framework was proposed and refined with empirical insights, where the concepts of uncertainty and learning emerged from data analysis. Collaborative projects operate in context characterized by high uncertainty and ambiguity; thus, these are highly sensitive to face perturbations produced by unknown unknowns (Wied et al., 2020). In this sense, their ability to overcome perturbations caused by unexpected issues becomes critical (Fey & Kock, 2022; Naderpajouh et al., 2020). Failing to address and overcome unexpected situations significantly increases the likelihood of project failure (Yang et al., 2022).

The second part of the research was aimed at comprehending the relationship between equivocality, governance, and their implications on the process of overcoming perturbations, as a project's success relies on its capacity to navigate through such challenges. In this section, a gap in the literature was identified and substantiated: "*how to effectively address disruptions in collaborative projects*". A framework was introduced with the intention of bridging this gap. This framework explains different ways of overcoming perturbations, focusing on the dynamic interaction between three relevant and well-known constructs during perturbations.

Traditionally, literature has linked these constructs through linear causality effects. However, in complex and uncertain situations, such as perturbations, the interrelationships between them become intricate and dynamic. It has been found that changes in governance approaches might lead to an increase in equivocality levels, but also, equivocality is mitigated mainly by the implementation of governance strategies. This research adhered to a more complex approach, by considering these relationships better explained by mutual causality and non-linearity. Even though there are academic articles that have explained the trade-off between equivocality and governance as made of mutual causality such as Majchrzak et al., (2015), this work adds a new dimension of the analysis, the learning capabilities of the organizations.

The evolution of this work has driven the researcher to consider organizational learning as a relevant capability to study during times of perturbations (Argyris & Schön, 1996). Perturbation forces the involved organizations to adapt and change, because if they do not, they might fail (Naderpajouh et al., 2020). The degree to which organizations adapt to the evolving circumstances arising from disruptions depends on their learning capabilities to effectively address these challenges. It was hypothesized in the literature review of the part II and then was also found in the cross-case analysis, that the organizational learning perspective offers novel explanations. Different learning capabilities moderate the relationship between equivocality and governance and the results of the process of overcoming perturbations (McClory et al., 2017).

Since organizational learning is a well-established research stream, this research applied the concept of single and/or double loop learning, adaptive or generative learning respectively (Argyris & Schön, 1996). A research framework is proposed and described in Figure 27, whose main objective was to describe the complex and mutual interrelationships between these constructs, highly relevant during perturbations. Through a comprehensive understanding of how these constructs interact with one another during disruptions, we propose plausible explanations about how projects can achieve resilience by overcoming perturbations. Complexity theory (Simon, 1996) has been applied as a research framework to capture the dynamic and non-lineal relationships between the constructs.

Specifically, the concepts of complex adaptive (Anderson, 1999), and complex generative (Chiva et al., 2010) systems. Both frameworks helped to describe the behaviours of systems characterized by adaptive or generative learning. We associated the concept of "edge of chaos" from complexity theory, as it is defined as bounded stability, with situations of perturbations in collaborative projects as these bring the project to react or adapt (Gell-Mann, 1994).

Complex generative systems are characterized by self-transcendence (Jantsch, 1980), inquiring the implicate-order, attention and dialogue (Chiva et al., 2010). Complex generative systems are characterized by self-adaptation (Anderson, 1999), a modification of the explicate order, concentration and discussion (Chiva et al., 2014). Both frameworks contributed to conceptualizing the systems formed by equivocality, governance and organizational learning during perturbations, characterizing their behaviours. This research framework represents the main contribution of this research, as this explains different patterns of potential reactions to perturbations in a collaborative project, based on the mutual interrelationships between equivocality, governance and organizational learning.

Two instances of perturbations have been analysed within a single (and successful) collaborative project to examine different patterns of reactions. Based on a round of interviews with project managers of different projects, the LOCUTIOS project was chosen as a sample of analysis. This project was able to overcome successfully two instances of perturbations. These situations were analysed using a cross-case analysis and two patterns of reactions were identified to overcome perturbations, to be resilient.

In both cases, equivocality issues were the trigger that led the project to the limited instability (edge of chaos), forcing it to react and adapt or transcend respectively. When generative behaviours have been identified, equivocality acted as a driver for expansive knowledge exploration enabled by a complementarity between relational and formal approaches and a double loop learning. None of them might exist by their own, as they are affected by the behaviour of the others and vice versa.

When equivocality acted as a barrier to knowledge exploration, with knowledge exploitation emerging as the primary knowledge search strategy, adaptability was identified. This strategy was more effectively executed through the implications of formal governance. Formal and relational governance acted as substitutes, either / or and these did not complement each other. Last, as the change implied mostly knowledge exploitation activities, single loop learning has been found as the predominant learning approach, leading to incremental knowledge outputs. These two patterns of evolution represent two manners of being resilient in a collaborative project, with different results associated with each one.

14.2 Research contribution.

The main contribution of this research is a conceptual research framework sustained in a set of propositions that, based on the interplay of governance, equivocality and organizational learning, explain different patterns of potential reactions to perturbations in a collaborative project. Since achieving project success is significantly dependent on the ability of a collaborative project to overcome perturbations, opening the black box of how resilience has been achieved reveals a novel contribution.

The conceptual framework introduces different constructs´ behaviours and configurations that have been exemplary to responding to perturbations, each exhibiting distinct results. This research is the first (as the authors acknowledge) that combines these three constructs and demonstrates how their relationships can evolve following diverse patterns, enabling a project to overcome perturbations and therefore participating on building project´s resilience. It emphasizes that similar inputs may produce completely different results, highlighting that the outcome of a system is not simply the sum of its individual components (Majchrzak et al., 2015). The contribution of the research framework can be summarized as follows: achieving resilience does not follow a unique path; instead, there are (at least) two approaches distinguished by the learning behaviours of the organizations, namely generative and adaptive resilience. The contribution of the research covers several research fields such as project management, innovation management and complexity theory.

Regarding the project management field, in the context of collaborative projects, the main contribution of the research is described as follows:

- The literature of project management has extensively considered the implications of the inherent uncertainty of projects as a matter of risk management (Naderpajouh et al., 2020). However, in more uncertain contexts such as collaborative projects, project success relies more on the ability of the organizations to navigate and overcome perturbations produced by unknowns' unknowns rather than accurate predictions of potential risks (Yang et al., 2022). There is a claim in the literature to change the focus from risks management to resilience management (Fey & Kock, 2022). This research aimed to address this gap by providing a conceptual framework to explain two different ways about how resilience has been achieved, as the result of the mutual interrelationship between equivocality, governance and organizational learning. Even though there are few empirical evidence that provided explanations about actions or strategies that enabled resilience in collaborative projects such as Wied et al. (2020) or Yang et al. (2022), no research to date (as far as the author´s acknowledge) has studied the process of “how” a project overcome perturbations.

- The second contribution to the field of project management is related to the implications of equivocality and governance into the project results. The implications of governance in project results have been largely studied in project management whose focus was basically the interplay between relational and formal governance and their effects in project success, either working as a complements or substitutes (Cao & Lumineau, 2015; Gulati et al., 2012; Solís-molina et al., 2020). However, in collaborative projects, a key issue to deal with in network of partners is equivocality, producing also either positive or negative implications in project results (Eriksson et al., 2016; Marcandella & Guèye, 2018). Changes in governance are aimed at improving the likelihood of project success, but these also might introduce equivocality in a network of partners. Then, if equivocality situations are not mitigated, project failure becomes a likely outcome (Frishammar et al., 2011), triggering also changes in governance either increasing or reducing the reliance on formal or relational approaches (Patel et al., 2018)

  The contribution resides on providing explanations about how these two relevant constructs interrelate to each other during perturbations, by following mutual causality approaches, affecting differently project results and enabling the project to be resilient. The literature extensively discussed the implications of governance and equivocality (separately) in project results, or how each one of them affects the other, following cause-effect analysis. Following the approach taken by Majchrzak et al., (2015), we have considered that these relationships are better explained by non-linearity and feedback loops, providing further explanations about how they interrelate to each other, and how the evolution of these interrelationships produces further implications in project results.

This research also provides contributions to the field of innovation management, specifically by the role played by equivocality on fostering innovation.

- Equivocality has been conceptualized as a double-edged sword in the context of innovation (Eriksson et al., 2016). On the one hand, equivocality facilitates development of diverging and competing interpretations that improve recombination of knowledge, it contributes to challenge the underlying assumptions of the partners and enables flexibility and creativity (Brun, 2016; Eriksson et al., 2016). On the other hand, equivocality situations might also exacerbate tensions among partners, restrain resources and make more difficult decision-making processes (Burström & Wilson, 2018). This research contributes to the field of innovation management by presenting a framework that elucidates the role of equivocality as a double-edged sword. While the dual implications of equivocality are known, the framework

delves into how governance and organizational learning come into play when each aspect of this double-edged sword is encountered. When equivocality acted as a driver for knowledge exploration, it has been found complementarity between formal and relational governance and double loop learning. When equivocality acted as a barrier the process of knowledge exploration, fostering knowledge exploitation, substitution effects in governance approaches (relying mainly on formal ones) and single loop learning have been found. These conceptual insights provide further explanations of the dual role of equivocality on project results.

- Additionally, the dual implications of equivocality in project results are conditioned by the sources that originate it. On the one hand, it has been found that when a diversity of interests leads to situations of equivocality, formal governance (executed by formal authority) contributes to align expectations and mitigate equivocality. On the other hand, equivocality originated by the diversity of knowledge domains might drive knowledge exploration if the partners share similar interest into the project. The sources of equivocality (diversity of interest or backgrounds) conditions its double implications on project results. This represents a contribution in the field of innovation by explaining how either diversity of interest or backgrounds among partners might affect project results through the dual implications of equivocality.

Last, this research develops a contribution to the field of complexity theories.

- Complexity theory is a well-established field of research with implications in biology, engineering, social sciences, organizational studies among others. This research has applied the concepts of complex adaptive and generative systems (Chiva et al., 2014) as a research framework as these enable the researcher to capture comprehensively the complex and non-lineal evolutions of interactions between components, being the outcome the result of the evolutionary interactions rather than the sum of the components (Majchrzak et al., 2015). Even though these frameworks were applied as methodological lenses to improve the understandings of the relationships between constructs, we also have developed an original conceptual implementation of complexity theories into the field of project management. Project management researchers have extensively applied deterministic lenses to capture the complex nature of project phenomenon, basically reducing research problems into cause-effects analysis (Padalkar & Gopinath, 2016). However, there is a recent claim in the field, to apply non-deterministic paradigms, based on the principles of product emergence, instability, self-organization and non-linearity (Arranz & de Arroyabe, 2008; E. Daniel & Daniel, 2019). This research adhered to this claim by considering the reaction to perturbations as complex system (Arranz & de Arroyabe, 2008), either characterized by self-organization (Anderson,

1999) or self-transcendence (Jantsch, 1980). The research framework represents a contribution of the methodological implementation of complexity theories in the field of project management.

The success of collaborative projects highly relies on their ability to effectively overcome perturbations originated by uncertain situations (Naderpajouh et al., 2020). There is a gap in the literature related to how teams navigate disruptions and achieve resilience. This research contributed to fill this gap by explaining different patterns to overcome perturbations. These approaches are distinguished by diverse learning behaviors that significantly impact the implications of equivocality and governance within unstable conditions. This research not only contributes by offering a framework that explains various system configurations enabling project resilience, but also goes beyond that.

Moreover, this study offers plausible insights into distinct behaviors associated with each construct. In simpler terms, it elucidates how governance approaches can function as supplements or complements, how learning behaviors may operate within single or double loops, and how equivocality can either drive or hinder knowledge exploration processes. Although the research primarily focuses on examining their interrelationships during moments of disruptions, its implications can also provide insights on the behaviour of each construct in various contexts.

For example, situations involving equivocality might foster knowledge exploration processes facilitated by double loop learning and the complementarity between formal and relational governance approaches. These scenarios are not limited to responses to disruptions but can also serve as explanations that characterize knowledge exploration phases within innovation projects. Formal governance might emerge as the primary tool to mitigate equivocality levels, enabled by single loop learning processes that facilitate knowledge exploitation activities in collaborative projects.

In this sense, the contribution of the research does not only provide plausible explanations about how a collaborative project might overcome perturbations, but also, how each construct acquires a specific behaviour, based on the relationships with the remaining ones. These explanations do not only cover the field of how to achieve resilience in projects, but also on how each construct may behave in collaborative projects.

14.3 Practical implications

The European Commission, for instance, has invested about 40 billion euros (2.3% of its budget) in the H2020 program to accelerate innovation and technology transfer (Klessova et al., 2022). Most of these efforts have been executed by collaborative projects. This research proposed a conceptual framework as the main contribution, associated with a set of propositions. Additionally, a set of good practices,

in the form of recommendations are proposed as practical implications for practitioners, either project managers, participants, and sponsoring organizations. These practical implications are framed in recommendations to project team members and managers, associated with the set of propositions already developed.

In order to maintain coherence, the practical recommendations are associated with each one of the propositions generated from the case study.

Regarding the first proposition (complex interdependencies in the process of overcoming perturbations), it has been derived from the case that the relationships between equivocality, governance and organizational learning are better explained by non-linearity and mutual causality. On the one hand, project managers should consider that changes in the governance in the form of changes in project plans, the increase or reduction of personal exchanges (meetings, face to face communications) or any other adaptation might generate equivocality situations. In a project formed by a network of partners with diversity of backgrounds and working methodologies, any change in governance might be subject to a variety of interpretations.

In the LOCUTIOS case, significant misunderstandings emerged between two groups regarding the interpretation of MRI data and its acquisition methods, originated from their distinct backgrounds. Even though it was apparently clear the meaning of such information at the beginning of the project, the developmental processes associated with it became susceptible to diverse interpretations. Altering the project's governance—be it linked to objectives or processes—could potentially exacerbate or mitigate these conflicting interpretations.

Managers should not assume a unique meaning for any information managed in the project, as each partner would understand it based on their own lenses. Diversity of perspectives and misunderstandings might be easily reached in the context of collaboration. In this sense, special attention should be given by managers to align the different partners' interests and to provide a field with technical people reaching mutual understanding. In a project embedded in a more predictable environments where the relationships are ruled by customer-supplier contracts, there is less likelihood to find diversity of interest (ultimately agreed by contracts) and diversity of interpretations, as each member can have a more accurate picture about the project. However, in collaborative projects, the meaning of information cannot be taken for granted and partners need to invest time and resources to provide a field where diverse backgrounds might reach mutual understandings.

Project managers should be aware that the implementation, change or absence of governance approaches might lead to an increase in equivocality between partners. In order to reduce them,

managers should implement also governance strategies such as increasing face to face meetings, supervision meetings, among others. Based on this research results, project managers might be aware that any change in governance exacerbates or reduces equivocality, initiating a loop of action / reaction.

> "*I should have been more of a pain in the neck for them at the beginning until I was satisfied that they really were working together, converging and not just working in parallel right" (…) "I should have gone and visited them and say, OK, what are you doing? Is this working toward the common goal?* " Project coordinator.

Behind the apparent simplicity of the concept, this statement given by the manager of LOCUTIOS project summarizes that any absence, change or adaptation of relational /formal governance might increase equivocality among partners. To mitigate these situations the partners might adapt governance, continuing the feedback loop. In this sense, we propose the following recommendations:

Recommendation 1: Governance and equivocality are critical aspects of a collaborative project, with mutual and dynamic implications. Ignoring one while focusing solely on the other, can yield significant repercussions on project outcomes and overall success.

Recommendation 1a: The project´s governance and its adaptations, either formal agreements or relational interactions, will inevitably produce situations of equivocality, where multiple and opposing interpretations will coexist.

Recommendation 1b: In order to reduce the diversity of interpretations, project managers should adapt either formal governance (changing milestones, objectives or agreements) or relational governance (increasing face to face communications, exchanges or meetings. These governance adaptations might either exacerbate or reduce the misunderstandings, continuing with a process explained by feedback loops.

Regarding the second proposition 2 (generative resilience); based on to this research, project managers might be aware that there is no single or unique way to overcome perturbations. It has been identified and modelled two manners of overcoming perturbations associated with different results. Based on the case, similar perturbations might trigger knowledge exploration or exploitation processes. During the first disruption in the LOCUTIOS case, it was observed that this disturbance catalyzed a knowledge exploration process by enhancing the reliance on relational approaches such as personnel exchanges and frequent communication. Consequently, an enhanced collaborative capacity linked to joint outputs (joint articles) was noted, providing evidence that positive outcomes can indeed be linked to disruptions.

Recommendation 2: Perturbations caused by unknown unknowns are not solely linked to negative project outcomes; they can also serve as catalysts for changes that can ultimately enhance the collaborative capabilities of partners.

During the first perturbation, tensions among partners due to diversity of perspectives triggered knowledge exploration processes. Due to the partners shared a common interest in addressing an issue, they were inclined to analyse various innovative approaches to resolve it, thereby fostering knowledge exploration. Knowledge exploration processes contribute to combining diversity of skills, knowledge and backgrounds, improving value co creation among partners. In this sense, an increase in knowledge exploration might be associated with an increase in the potential value added by the solution.

Nonetheless, the process of converging diverse disciplines to achieve a shared outcome and aligning a variety of understandings regarding the information, necessitates both time and resources. In this sense, personal exchanges, face to face meetings, frequent interactions, etc. contribute to generate trust among partners. Trust among partners contributes to reduce misunderstandings and tensions and enables exploring different solutions to solve a problem. However, these relational processes require time and resources.

In this sense, project managers might consider the following strategy to overcome a perturbation. If misunderstandings arise as a consequence of the diversity of backgrounds, sharing similar interest, they might stimulate personal interactions, exchanges and communication between the partners involved. Sooner or later, partners would be able to reach a common understanding and to complement the backgrounds to solve the issue, generating synergies among them. This was evidenced in the first perturbation of the LOCUTIOS case study. If they are successful on this endeavour, it is likely that the collaborative capacity among them would be improved, as trust among them has been enhanced. In this sense, we propose the following recommendation:

Recommendation 3: In the event of disruptions, project managers can encourage partner interactions aimed at integrating multiple perspectives to address a problem, especially when partners share similar interests.

Recommendation 4: A perturbation originated by unpredictable situations might be considered as an opportunity to improve the quality of collaboration between partners.

In the LOCUTIOS case, the partners devoted approximately 8 months (equivalent to 20% of the project's duration) to establish a shared understanding of MRI data acquisition—a measure not initially planned but taken as a contingency to address the disruption stemming from a knowledge gap

between teams. As evidenced by the case, the process of overcoming this initial disruption enabled the amalgamation of diverse knowledge domains, leading to collaborative outputs and an enhanced quality of collaboration. However, this resolution demanded significant time and resources, resources that may not always be readily available in a project. Double-loop learning, knowledge exploration, and relational approaches are often linked with slower and more resource-intensive procedures.

Recommendation 5: Project managers face the decision of how to respond to disruptions, recognizing that relational approaches facilitate the exploration of knowledge and the convergence of multiple perspectives, albeit typically requiring additional time and resources.

Regarding the third proposition (adaptive resilience), the diversity of interpretations and perspectives not only aids in exploring solutions but can also serve as a barrier to achieving mutual understanding and aligning partner expectations. If these conflicting perspectives are not mitigated, they could pose a challenge to the project's continuity. When a project faces a perturbation, the diversity of perspectives about how to proceed might be exacerbated. In the case study, it has been identified another way to overcome perturbations, when the diversity of perspectives rather than contributing to knowledge exploration, restrains resources and create tensions amongst partners.

During the second perturbation, equivocality issues arose due to the diversity of (and opposing) perspectives about how to proceed. The involved partners held differing scientific interests, leading to the emergence of divergent paths rather than complementary ones to address the disruption. Increasing reliance on relational approaches did not aid in improving their relationships; instead, it would have exacerbated their differences. Consequently, formal governance, embodied by the authoritative role of project managers, emerged as the primary mechanism to navigate this disruption. Contrary to prioritizing knowledge exploration as the primary activity for knowledge creation, project managers directed each partner to continue exploiting their own knowledge. Similar to the first disruption, situations of equivocality necessitated governance adaptations. However, in this instance, the adaptation that enabled continuity involved heightened dependence on formal governance (utilizing the authority of project managers) as the primary tool to address the disruption.

In this case, as personal interactions rather than improving knowledge flows, increase tensions among partners, formal authority emerged as the main vehicle to solve conflictive situations. The decisions taken by formal authority are more associated with exploiting existent knowledge, rather than exploring solutions among partners. Moreover, this decision has been found effective in the process of overcoming perturbations, when the partners might not reach agreements by themselves due to the diversity of interests.

Furthermore, the results linked to these decisions primarily involve improvements in existing processes, products or technologies, often without delving into alternative or innovative approaches. Consequently, in periods of disruption, project managers may play a role in resolving conflicts originated by differing interpretations of the way forward by making authoritative decisions rather than mandating collaborative / relational efforts among partners. It has been observed that in situations where there is an irreconcilable diversity of perspectives, the formal authority of managers tends to diminish these differences and encourage partners to focus on their individual tasks, thereby reducing collaboration.

Due to the second disruption, the partners managed to blend their distinct solutions into a partially integrated joint solution. These efforts aimed at exploiting existing resources were achieved more swiftly and with fewer resources than the exploratory initiatives. Consequently, exploitative activities tend to be associated with formal governance implications, rapid yet superficial learning cycles, and a reduced investment of time and resources. However, it has been discovered that the outcomes resulting from these exploitative methods could negatively impact the final project outcomes. This is because they stem from the integration of individual, disparate outputs rather than a collaborative output.

Recommendation 6: It is crucial to perceive a disruption as a potential threat within a collaborative project, as it holds the capacity to hinder the collaborative prowess among the involved partners.

Recommendation 7: Project managers should take an active role and make decisions when partners might not reach agreements by themselves, reducing the intensity of their collaboration among the conflicting parts if they do not share similar interests in the project.

Recommendation 8: Overcoming disruptions by relying on managerial authority may yield quicker results, but this approach may come at the expense of the value added through co-creating the output.

Considering the sixth proposition (the double-edged sword of equivocality), the following phrase summarizes a managerial issue in many collaborative projects:

> *"Their interest was not in solving the problem, but rather in creating some codes (..). The actual problem itself did not generate enough interest for them to explore how the voice works. That scientific curiosity was not as present within that group"* WP5 Team member. - Group 6.

The diversity of perspectives is common in all type of projects. However, it is exacerbated in the context of collaboration, as each partner has their own background and interest regarding the project.

Reaching mutual understanding about information and aligning partners´ expectations become essential for any project manager in a collaborative project. As a result of this research, it has been identified that multiple perspectives might arise inherently in a network of partners, however the sources of such misunderstandings condition their implications.

It has been identified during the first perturbation that partners shared similar willingness and scientific curiosity to solve the problem and overcome the perturbation, even though they have struggled to reach a mutual understanding about technical aspects. In the second perturbation, the partners were able to quickly reach mutual understanding about technical aspects, despite not having shared scientific interests in resolving the problem. The diversity of backgrounds and interests conditioned the further reaction to perturbations.

Extrapolating the findings related to the first case, if the partners share similar interests into the project, during times of perturbations, they might tend to find solutions to tackle the problem, more promptly looking for a solution that benefit the project itself, a common goal. Potential misunderstandings might arise as each one of them would understand the problem and solutions based on their own backgrounds. However, the multiplicity of perspectives might contribute to the process of addressing the disruptions, as partners share a common goal. Additionally, sharing similar interests might help to implement relational approaches such as meetings, personal exchanges, face to face communication. This would be associated with an increase on partner´s trust among each other. In this context, the diversity of perspectives and understanding about information might be reduced by relational approaches, enabled by shared interest. In this sense, understanding the hidden agenda of each partner becomes crucial for project managers.

Recommendation 9: In the process of overcoming perturbations, managers should consider if diversity of perspectives arise, their origins and the actions taken to manage them relying on relational exchanges or formal authority.

Recommendation 10: In conflictive situations originated by diversity of perspectives, project managers might encourage relational approaches between partners if they share similar scientific interests.

In this case, during the first perturbation, diversity of perspectives originated by the existence of different knowledge backgrounds has contributed to generate solutions that combines knowledge from different sources. The positive implication of diversity is conditioned to share similar interests into the project. In this sense, joint outputs originated by the synergies between different knowledge domains was found possible when the partners shared similar interests, regardless the diversity of

backgrounds. These outputs were enabled thanks to the increasing reliance of relational exchanges and the trust built upon the project.

Recommendation 11: Project managers should invest time and resources to align partners´ interests to be able to fruitfully convert the diversity of backgrounds and skills into joint outputs.

However, in the other hand, if partners do not share similar interest, developing common outputs as the result of collaboration, would be a more difficult task. This has been found during the second perturbation. The partners tended to protect their own interests and it might not matter if they are able to understand each other about technical issues. They might try to find the way to propose solutions that are aligned with their own interests rather than a common goal.

A variety of interpretations often emerges during periods of disruption, driven not only by the turbulence itself but also by the diversity of interests among stakeholders. In this second perturbation, formal authority has been recognized as an effective governance approach to mitigate equivocality and enable the project to continue. Therefore, it is crucial for managers to cultivate trust among their partners in their capacity, as in situations of conflict, this role can significantly aid in resolving equivocality arising from conflicting interests.

Recommendation 12: In conflictive situations originated by diversity of perspectives, project managers might leverage formal authority to make decisions if the partners have opposing interests.

Recommendation 13: Project managers should actively build trust in their role among their partners. This is particularly important during periods of disruption, as their authority can play a pivotal role in resolving disputes arising from the diversity of interests among partners.

Table 11 summarizes the practical recommendations for project managers, coordinators and sponsoring organizations associated with the main results of this research:

Proposition	Recommendation
Proposition 1: During perturbations, equivocality, governance and organizational learning constitute a complex system made of mutual causality and non-linearity on the relationships.	Recommendation 1: Governance and equivocality are critical aspects of a collaborative project, with mutual and dynamic implications. Ignoring one while focusing solely on the other, can yield significant repercussions on project outcomes and overall success.
	Recommendation 1a: The project´s governance and its adaptations, either formal agreements or relational interactions, will inevitably produce situations of equivocality, where multiple and opposing interpretations will coexist.
	Recommendation 1b: In order to reduce the diversity of interpretations, project managers should adapt either formal governance (changing milestones, objectives or agreements) or relational governance (increasing face to face communications, exchanges or meetings. These governance adaptations might either exacerbate or reduce the

	misunderstandings, continuing with a process explained by feedback loops.
Proposition 2: Generative resilience is characterized by double (generative) loop learning, complementarity between relational and formal governance approaches and equivocality acting as a driver for knowledge exploration.	Recommendation 2: Perturbations caused by unknown unknowns are not solely linked to negative project outcomes; they can also serve as catalysts for changes that can ultimately enhance the collaborative capabilities of partners.
	Recommendation 3: In the event of disruptions, project managers can encourage partner interactions aimed at integrating multiple perspectives to address a problem, especially when partners share similar interests.
	Recommendation 4: A perturbation originated by unpredictable situations might be considered as an opportunity to improve the quality of collaboration between partners.
	Recommendation 5: Project managers face the decision of how to respond to disruptions, recognizing that relational approaches facilitate the exploration of knowledge and the convergence of multiple perspectives, albeit typically requiring additional time and resources.
Proposition 3: Adaptive resilience is characterized by single-loop learning, substitution effects between relational and formal governance approaches, and equivocality acting as a barrier for knowledge exploration, promoting knowledge exploitation processes.	Recommendation 6: It is crucial to perceive a disruption as a potential threat within a collaborative project, as it holds the capacity to hinder the collaborative prowess among the involved partners
	Recommendation 7: Project managers should take an active role and make decisions when partners might not reach agreements by themselves, reducing the intensity of their collaboration among the conflicting parts if they do not share similar interests in the project.
	Recommendation 8: Overcoming disruptions by relying on managerial authority may yield quicker results, but this approach may come at the expense of the value added through co-creating the output.
Proposition 6: The sources of equivocality condition the either positive or negative implications of equivocality in performance results.	Recommendation 9: In the process of overcoming perturbations, managers should consider if diversity of perspectives arise, their origins and the actions taken to manage them relying on relational exchanges or formal authority.
	Recommendation 10: In conflictive situations originated by diversity of perspectives, project managers might encourage relational approaches between partners if they share similar scientific interests.
	Recommendation 11: Project managers should invest time and resources to align partners´ interests to be able to fruitfully convert the diversity of backgrounds and skills into joint outputs.
	Recommendation 12: In conflictive situations originated by diversity of perspectives, project managers might leverage formal authority to make decisions if the partners have opposing interests.
	Recommendation 13: Project managers should actively build trust in their role among their partners. This is particularly important during periods of disruption, as their authority can play a pivotal role in resolving disputes arising from the diversity of interests among partners.

Table 11: Practical implications of the research

14.4 Limitations and future research lines.

This doctoral thesis presents limitations inherent to any research work. Any research study should be aware of its limitations as these boundaries define the obtained results and enable the proposal of new advancements in the field of knowledge. In our study, we must consider limitations related to the methodology employed, the specific sample used in the empirical work, the characteristics of the systems under analysis and of course, the scope of the conducted analysis.

1) Regarding the methodology used, this qualitative study aims to build new theoretical contributions through abductive reasoning. This approach does not seek to test the established theories. Instead, it is limited to deriving these theories, which are grounded in a combination of the existing theoretical frameworks and the evidence derived from empirical work. It is important to note that since the research is qualitative in nature, the results provide additional (and plausible) explanations for an underexplored phenomenon, rather than generalizations of system configurations and project outcomes (Sætre & Van de Ven, 2021). The propositions that emerge in this study are presented for subsequent testing and verification.
2) The sample for the empirical work is based on a case study and its cross-comparative analysis. It is evident that using case studies imposes a limitation in terms of sample representativeness. In our study, the in-depth case study and its comparative analysis provide a method that offers a solid foundation for the conducted analysis, but in any case, generalizing the results is far from being justifiable.
3) The empirical evidence in this study is limited to collaborative projects funded by the European Commission, where the Commission acts as a sponsor and delegates the management to the coordination team. Then, as it was defined in Part II section 8.1, this research is bounded also to exploratory projects, characterized by high scientific or technological uncertainty. According to the TRL´s score, this typology of projects cover the range from 1 to 4, being them considered as basic research by the scientific community (vom Brocke & Lippe, 2015).
4) It is also important to acknowledge that the participating organizations in the case study were only research centres. This limitation should be recognized, as the project involved partners from diverse scientific domains, although they all possessed a background in science. The results may differ if the partners belonged to industrial or public organizations, for instance.
5) Although the research design in its final form allows for contributions to the field of interest in this study, it has had to assume certain limitations. Firstly, the research framework assumes that during perturbations, equivocality and governance as subsystems are involved. The interaction between these two is moderated by the role played by the organizational learning, and it's worth noting that this assumption is what leads to the primary contribution of this work. This composition of the framework includes a limitation in that it does not account for the involvement of any other systems or elements that could have an impact on the results of overcoming perturbations. Although the model's foundation is rooted in the theoretical

framework that has been analysed, it cannot be ruled out that there may be other organizational components that could be beneficial to include in this analysis.

This research has been confined to a specific developmental framework and has had to acknowledge certain limitations to make it feasible. Furthermore, as a result of the research, reflection, and analysis work, new opportunities for advancement in the scientific field and practical application have emerged or been identified. The author presents these opportunities with the hope that both academia and industry can make progress in this area of study.

1) Future research might investigate the relationships between the related constructs in diverse contexts, including collaborative industrial projects with higher technology readiness levels (TRLs) involving networks of private, public, and academic organizations. Analysing the impact of technological, sectoral, and organizational diversity on the proposed research framework would be valuable (Raesfeld et al., 2012).
2) Another promising avenue would be to apply the proposed framework in a case where the collaborative project has not been able to overcome perturbations in order to understand how the three constructs interrelated to each other in a failure case.
3) Resilience has been researched in different fields such as engineering, social science, biology among others. There are studies such as Wied *et.* al (2020) that have conceptualized resilience according to the capacity to resist and/or recover from perturbations. This research has assumed resilience as the dependent variable, and different system´s configurations that enable it. However, future research might inquire in how the implications of the framework developed in this work might impact on different resilience characteristics or components (resistance or recoverability, for instance).
4) Lastly, studying the behaviour of the three constructs in relation to knowledge creation would be a highly promising research direction. Knowledge creation is the key process to deliver innovation in collaborative projects, and understanding how these constructs influence and interact with each other in this process can provide valuable insights (Faccin & Balestrin, 2018).

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16. Annex.

16.1 Documentation 1. Protocol of interviews section 1.

Following, there is a list of predefined questions that guided partially the interviews.

1) *Could you briefly explain me what was the project about?*
2) *As a project coordinator, do you think the project achieve its objectives?*
3) *What have been the main challenges of the project?*
4) *Do you remember the main issues and problems during each one of the phases? What have you done to overcome them?*
5) *The broad diversity of partner´s backgrounds (in terms of cultural, knowledge and working styles) has represented a challenge to manage?*
   According to you, what have been the positive implications of diversity of partners and the negative ones…
6) *Have you faced different understandings/ interpretations about what the consortium should do in specific moments? Frequently? How did you manage them?*
7) *Have you faced tensions or conflicts between partners? Which were the main reasons? How did you manage them?*
8) *As a project coordinator, have you need adapt governance/ managerial actions with the consortium of partners according to the project evolution? How?*
9) *As a consortium of partners, have you had previous experience working together? How was the team working at the beginning and at the end?*
10) *How did you integrate continuously the knowledge that were being developed through the project? Did you need specific management efforts to coordinate all the knowledge and outputs during the project?*
11) *Have you improved the collaboration along the project? How? Why?*

16.2 Documentation 2. Second round of interviews: LOCUTIOS project case study. Protocol of interviews:

- What was the relationship between the main partners in the team like?
- Were there different interpretations about the objectives of WP, the way of working, the tools to be used, etc.?
- What types of tensions arose during the collaboration? What were the causes?
- How were these tensions resolved?
- How has the collaboration between them been at the beginning and at the end?
- What factors have contributed to improving/worsening the relationship between the partners?
- What and how were the main learning activities and outputs in the relationship between partners?
- Do you consider the collaboration between the partners improve or decrease after the tensions among them?

16.3 Documentation 3: Semi-structured interviews summary, Section 2:

Stakeholder.	Organization/position	Duration
Project coordinator.	Group 2 / Project coordinator (WP1)	62.23min
Project coordinator.	Group 2 / Project coordinator (WP1)	58.24 min
Scientific coordinator.	Group 6 / Scientific coordinator (WP1)	35.111 min
Scientific coordinator.	Group 6 / Scientific coordinator (WP1)	36.12 min
WP8 leader	Group 6 / WP8 Leader	51.57 min
WP8 leader	Group 6 / WP8 leader	55.33 min
WP7 leader	Group 1 / WP7 leader	44.04 min
Project team member	Group 4 / PTM (Project team member) WP3	48.51 min
Project team member	Group 7 / PTM WP4	35.52 min
Project team member	Group 3/ PTM WP4-WP2	20.46 min
Project team member	Group 7/ PTM WP4	33.22 min
Project team member	Group 6/ PTM WP5	39.12 min
Project team member	Group 5 / PTM WP6	43.57 min

16.4 Documentation 4. Documentation summary. Section 2.

Documentation	Length
Periodic reports (47 in total)	10 pages (av.)
Executive meeting minutes (25 in total)	4 pages (av.)
DoW (declaration of work)	70 pages
Final report	62 pages.
European Commission report (3 reports)	10 pages (av.)

16.5 List of open and axial coding

Due to space limitations, the verbatims are not included in the following table. During the case description and analysis in section 12, the most descriptive evidence is shown in each case to support the author´s interpretation. However, in the following Table 12, the list of 70 open codes categorized by subsystems and concepts are further detailed.

Code nº	Context	Open Code	Concepts	axial code	Subsystem
E1	Perturbation 1	Missunderstandings between partners related to the "product"- MRI data	Missunderstandings	Tensions	Equivocality
E17	Perturbation 1	Missunderstandings between partners related to managerial issues			
E16	perturbation 2	tensions among partners hinder collaboration and knowledge exploration			
E2	perturbation 2	Missunderstandings between partners related to the process - Unification strategy			
E3	perturbation 1	Different interpretations about the project goal	Diversity of interpretations	Equivocality sources	
E4	Perturbation 1	Different interpretations about contracts			
E14	perturbation 1	Different parnter´s expectations about the other´s knowledge	Diversity of expectations		
E20	perturbation 2	The lack of intrinsic motivation as a barrier to build trust between partners	Diversity of interest		
E11	perturbation 2	Different interests (utility) of the partners in the project			
E12	perturbation 2	Different (scientific) interests of the partners in the project			
E9	overall project	Geographical proximity between partners	geographical diversity		
E8	overall project	Scientific diversity of parnters	Scientific diversity		
E6	overall project	Scientific complexity related to the diversity of partners			
E20	perturbation 1	Scientific GAPs			
E10	overall project	Effects of the cultural diversity	Cultural diversity		
E21	perturbation 2	Missunderstandings reduction by authoritive decisions	equivocality reduction	equivocality reduction	
E22	perturbation 2	Missunderstandings reduction by superficial learning			
E5	perturbation 1	Mutual understanding driven by high collaboration into the project and trust among partners			
G12	overall project	Low quality of reporting	Reporting	formal governance	governance
G16	Both perturbations	Positive influence of the sponsor in the project	sponsor implication		
G3	perturbation 2	Different allocation of resources for each partner according to their different interests in the project	Resource allocation		
G9	perturbation 1	Contingency (emergent and unplanned) actions: Hire an external organization	Outsourcing. Contractual changes		
G6	overall project	Ambitious & ambigous initial goal definition	Goal definition		
G7	perturbation 2	Flexibility to adapt the project goal			
G27	overall project	Difficulties to allign Stakeholders into a common goal	Stakeholders management		
G5	overall project	Difficulties to manage different interests in a R&D project			
G8	overall project	Proper initial project plan	project planning		
E13	perturbation 1	Lack of predictability capacity of managers/ members			
G29	perturbation 1	Lack of accuracy of formal agreements	Contractual agreement		
G11	perturbation 2	Contingency (emergent and unplanned) actions: Technical solutions (dividing the problem in parts rather than an unification) decided by the PM and SC	Formal authority		
G28	overall project	Levels of organizations (layers) within the project	Project strucure		
E5	perturbation 1	Contractual implications related to missunderstandings	Managerial issues		

G14	overall project	Increasing supervision along the Project lifecycle	supervision	relational governance	governance
G22	perturbation 2	Lack of personal supervision of PM to each partner at the beginning of the project			
G21	perturbation 1	Improved collaboration thanks to the visits between partners. Improved understanding about technical issues.	exchange resources		
G10	perturbation 1	Contingency (emergent and unplanned) actions: Exchange technical resources			
G23	perturbation 1	Positive results of general meetings on the collaborative capacity of the consortium	Meetings		
G15	overall project	Lack of technical expertise of the PM	Leadership		
G24	perturbation 2	Positive consequences of scientific leadership on consortium collaboration			
G26	perturbation 2	Positive effects of shared leadership between Scientific coordinator and Project Manager			
G2	overall project	Technical knowledge of SC in a diversity of fields			
G25	overall project	The effects of leadership styles on partners´collaboration			
G18	Both perturbations	Interpersonal relationships to build trust	Interpersonal relationships		
G17	perturbation 2	The impact of the EGO into the interpersonal relationships	Scientific EGO		
G19	perturbation 1	Increasing the efforts spent into the project to build trust	Trust		
G4	Both perturbations	Effects on trust of the different partner´s interest			
G31	Both perturbations	Consequences of trust in the collaboration capacity			

OL18	perturbation 1	Deep and slower learning process related to bridging scientific domains and knolwedge exploration	learning behaviours	double loop Learning	Organizational learning
OL9	perturbation 1	High collaboration to integrate knowledge from different WPs (knowledge exploration)			
OL17	overall project	The greater the proximity the faster the learning.			
OL11	perturbation 1	Learning capacity to adapt project strategy, formal contracts and relational exchanges			
OL1	perturbation 1	Technical learning required to integre knowledge from different domains (bridge gaps: knowledge exploration)			
OL22	perturbation 1	Higher learning due to closer personal interactions between partners			
OL12	perturbation 1	Learning related to solve the scientific problem			
OL7	perturbation 1	Learning driven by high parnter´s motivation to reduce scientific missunderstandings			
OL3	perturbation 2	Superficial learning to speed up project progression		Single loop learning	
OL23	perturbation 2	Superficial learning to integrate separete outputs			
OL4	perturbation 2	Superficial learning due to low partner´s commitmet			
OL24	perturbation 2	Superficial learning originated by lower partners interaction			
OL2	overall project	The relevance of micro level (technical) collaboration to improve inter-module learning	micro level learning	learning competencies	
OL15	before project	Previous experience of partners in EU projects	Previous experiences		
OL16	before project	Lack of competences´ testing			
OL5	perturbations	Different learning speed according to the parnter´s allignment	learning speed		
OL20	perturbation 1	Cross learning as the main outcome	learning outcome	Learning outcome	
OL8	perturbation 2	Inter-organizational learning: difficulties to integrate knowledge (outputs) from different teams	learning barriers	learning barrier	
OL14	before project	Lack of previous experiences working together	Previous experiences		
OL19	perturbation 1	Missuderstandings as a driver for learning and knowledge exploration	learning triggers	learning driver	

CC1	Both perturbations	Different results (collaborative capacity) according to the modules (WPs)	intermodule collaboration	collaboration capacity	Perturbation results
CC3	Both perturbations	Different collaborative results according to the fitting between partner´s motivation			
CC2	Perturbation 1	Increase in the global collaborative capacity through the project lifecycle	collaboration evolution		

Table 12: List of open and axial codes

16.6 Data analysis: subsystem´s behaviours:

An example of how we have analysed the behaviours of each of the subsystems is proposed as follows:

Subsystems	Verbatim	Subsystem´s behaviours
Equivocality	"If both parties are willing to cooperate they will overcome these missunderstandings easily and that is really nurturing" OG (Dialogue rather than discussion) "De los grupos, el segundo grupo que estaba Sten Ternstron, **aunque tuvieron muchas dificultades técnicas, si tenían un interés por solucionar ese problema y un compromiso por solucionar ese problema porque llevan años investigando sobre la voz.** Así que hay el interés de hacer las cosas. En el otro, El interés no venía por resolver el problema, sino porque se hacer unos códigos y "hay una aplicación más, no?, me puede servir para aviones, para el corazón humano y para la voz". Pero el problema en si, no les generaba suficiente interés, sí," MA (highly commited to solve the project - focussed on exploring alternatives). (Attention rather than concentration). "there were some frictions at one of these general meetings that it was, well, people were a little bit "you are not delivering what you should do, this is not useful". But then once we got down to two actually, well, "h*ow can we solve this problem? "* It w**as solved in a very constructive way**, and it led to a a very close collaboration for several years and resulting in several different high profile publications. So the outcome was very successful" (Dialague) OE "Casi estuvimos un año. Para buscar alternativas y **al final encontramos que otro grupo de investigación de fuera del proyecto,** había publicado database con estas geometrías que eran fundamentales para el WP5" MA. (Attention) "And then during that session, somebody was Googling and found that a Cannadian group had already made the nice round meshes that La Salle had been asking for. Which was embarrassing to the people of KTH that have been working on, trying to make those messhes and not being aware of the Canadian work." ST (Dialogue)	Equivocality as a driver for expansive learning: Generative behaviours characterized by **dialogue and attention.** Even though the main team had a GAP of expertise, they were commited to solve the problem. On an equivocality situation they were open to recieve feedback, suggestions and an student exchange to tackle the problem. Exploring alternatives is a characterization of generative behaviours **(attention).** Being open to receive constructive feedback that would reduce the knowledge gaps is also a sign of **dialogue.** Thanks to closer collaboration, the equivocality issues were reduced and both parties were able to bridge scientific gaps **(dialogue)**

Table 13: Example of data analysis in subsystem´s behaviours

Due to space constraints, the analysis and interpretation of the subsystem's behaviours for each perturbation are presented without the inclusion of the verbatim excerpts. Previous example shown in Table 13 provides evidence of the entire data analysis process. In Section 12, the case analysis furnishes ample evidence of the system's behaviours to ensure readability and rigor in the interpretation of both cases.

<u>Perturbation 1</u>

Subsystems	Subsystem´s behaviours
Equivocality	Equivocality as a driver for expansive learning: Generative behaviours characterized by **dialogue and attention.** Even though the main team had a GAP of expertise, they were commited to solve the problem. On an equivocality situation they were open to recieve feedback, suggestions and an student exchange to tackle the problem. Exploring alternatives is a characterization of generative behaviours **(attention).** Being open to receive constructive feedback that would reduce the knowledge gaps is also a sign of **dialogue.** Thanks to closer collaboration, the equivocality issues were reduced and both parties were able to bridge scientific gaps **(dialogue)**
Governance	Governance approaches complemented each other as enable/compensator form. RG compensate the limitations of FG and also FG was adapted based on Relational interactions. As a result, closer collaboration between partners enabled solving scientific issues. Merging WPs that were initially isolated due to the high uncertainty of the tasks **(Inquiry).** Including external actors that helped the team to bridge scientific gaps (**attention**). Change plans and send an student to do an exchange program in other university in order to bridge gaps between partners **(inquiry)** Fluent **dialogue** between partners (at micro-level) to get mutual understanding regarding scientific issues. Decisions and solutions were made by partner´s agreements rather than authority of coordinators.
Organizatio nal Learning	**Attention** to find solutions that enable the team to solve the problem, reframing the existent knowledge and procedures (double loop). **Inquiry** on learning results (new knowledge from different scientifc domains as each partner increased their knowledge boundaries).

Table 14: Subsystem´s behaviours during perturbation 1

Perturbation 2:

Subsystems	Subsystem´s behaviours
Equivocality	Equivocality acting as a barrier for knowledge exploration. Both partners had a high scientific maturity levels and they´ve worked separately during the project. During the perturbation, they focussed on technical issues that needed to be solved to unify codes. During the meetings they´ve exchanged arguments and counterarguments, with no collective inquiry. It was characterized by **discussion** rather than dialogue. Equivocality issues led the team an **improvement** in their knowledge background rather than an inquiry. Even though the main objective was to provide an unified code, during the perturbation, none in the consortium of partners provided a solution that fully satisfies the requirements. Rather, the main partners fought among each other to do the work in their own platform, being this an example of **concentration** rather than attention
Governance	Governance approaches acted as a either/or with lowt adaptation. Formal authority emerged as the vehicle to solve tensions Formal governance provided the blueprint of working and the relational interactions, so, each partner worked in their own code. As the project evolves, the scientific maturity of each team started to vary among each one, showing different level of implications between partners. In this sense, relational governance didn´t compensate the limitations of FG, as it did not contribute to translate what the agreement said into real contributions. Then, Formal agreements have not been adapted to overcome the perturbation and relational approaches did not contribute to provide an overreaching solution. Each partner reinforced their position and they were unflexible to give up. **Discussion** rather than attention. During the meetings they have focussed also on details rather than the whole picture (concentration). **Concentration**. Due to the team was not able to reach an agreement, the decision has been made by the coordinators (authority), thanks to a **strong scientific leaderships** that enable both parties to reach agreements and to overcome the perturbation. Adaptative---> strong leadership/ authority
Organizational Learning	The learning processes have been mainly characterized as a single loop. Even though the scientific contributions of each partner were considerable, no joint articles can be found. This is an evidence of indiviidual learning rather than joint learning, as well as an **improvement** on their existing knowledge domain rather than inquiry process of reconceptualizing knowledge foundations. The partners belong to different scientific schools of knowleldge, but in conflictive situations, they stayed closer to what they know, rather than openning their minds and look for overraching solutions. **Concentration** rather than attention. The exchange student enabled both teams to improve coordination and helped to bridge operative issues regarding the inputs and outputs of the final solution. The exchange resource did not help to provide mutual understanding in terms of providing an unified solution.

Table 15: Subsystem´s behaviours during perturbation 2