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Understanding the socio material complexity in context of major projects: a study of three infrastructure projects

Sanaa El Boukri

Ecole des sciences de la gestion, Université du Québec à Montréal

Monique Aubry

ESG UQAM

Serghei Floricel

uqam

Understanding the social complexity in major projects

Track: project experiences

Sanaa El Boukri, School of Management, Université du Quebec à Montreal (ESG UQAM),
Montreal, Canada. el_boukri.sanaa@uqam.ca

Monique Aubry, School of Management, Université du Quebec à Montreal (ESG UQAM),
Montreal, Canada. aubry.monique@uqam.ca

Serghei Floricel, School of Management, Université du Quebec à Montreal (ESG UQAM),
Montreal, Canada. floricel.serghei@uqam.ca

Department of Management

315 Sainte-Catherine E, Montreal, QC H2X 3X2

Canada

Understanding the social complexity in major projects

Abstract

Major projects encounter complexity, which can significantly impact their performance. The field of project management extensively explores and addresses complexity, but it remains a contentious topic due to fragmented literature, ambiguous interpretations, lack of consensus on definitions and components, and the continual emergence of new forms. This article adopts a practice view and actor network theory to understand the social processes that underlie the dynamics of complexity in major project contexts. This aims to reveal perceptions, strategies, decisions, changes, and practices - involving both human and non-human actors - throughout the project, thereby shaping the project itself. Three north American major projects were selected for qualitative data collection, including interviews, observations, and internal documents. The analysis is inspired by grounded theory. The findings suggest a socio-material conceptualization of complexity. Three configurations of temporal complexity were identified: prospective, concurrent/real-time and retrospective. These configurations manifest and materialize through the interactions of human and non-human actors within the project network, encompassing contextual, organizational, and project-level dimensions. The temporal modes of social complexity are influenced by collective sense-making, recognition and understanding of tensions.

Keywords: social complexity, practices, major project, infrastructure, actor-network.

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Introduction

Complexity is associated with projects across various industry sectors (Bosch-Rekvelde et al., 2018), particularly large scale that have significant social, technological, environmental, and sometimes even political and regulatory impacts (Bosch-Rekvelde et al., 2011; Flyvbjerg, 2017; Orueta and Fainstein, 2008; Vickerman, 2017). Project complexity is a prominent topic in project management research since the publications of Baccarini (1996) and Williams (1999). The International Journal of Project Management dedicated a special issue to understanding, reducing, and managing complexity, which contributed to the development of a comprehensive literature on project complexity (e.g., Li and Guo, 2011). In the practical field, the Project Management Institute (PMI) extended the PMBOK® Guide to include "Navigating Complexity: A practice Guide" (PMI, 2014) to assist project managers in developing the flexibility to cope with unpredictability and change. This is driven by the ongoing concern over the performance of major projects and recurring cost overruns and time delays (Premius et al., 2008). The increasing complexity is identified as a contributing factor. (Bjorvatn and Wald, 2018; Elia et al., 2020; Nguyen et al., 2019). As a result, there has been a proliferation of work on "managing project complexity" (e.g., Maylor and Turner, 2017; Whitty and Maylor, 2009), focusing on modeling complexity, understanding interdependencies in complex systems, and exploring managerial implications within the project context.

Despite research development, there is still a need to expand and diversify perspectives when studying complexity in terms of emergence, uncertainty, and unpredictability. This will allow for a deeper understanding of complexity in project contexts and enable the development of skills that are well-suited to address these challenges. (Bakhshi et al., 2016; De Rezende et al., 2018). Limitations such as the lack of consensus around the concept and definition of project complexity, the lack of theoretical integration and the fragmentation of knowledge are defended. The concept of complexity is described as highly plastic, and the idea of a uniform conceptualization is seen as a simplification (Mikkelsen, 2021).

It is essential to diversify paradigms and perspectives to facilitate cross-fertilization and provide a range of understandings and explanations of project complexities that emphasize pluralistic contexts rather than seeking a singular solution (Denis et al., 2007; Geraldi et al., 2008; Söderlund, 2011). In line with this dynamic and pluralistic perspective, this research aligns with the recognition of multiple objectives, actors, interests, power dynamics, and knowledge-based work processes (Denis et al., 2007).

Furthermore, this research aims to contribute to the dynamic approach to complexity, which recognizes non-linearity, change, and the emergence of unpredictable relationships and behaviors (Wood, 1986). This orientation is motivated by the limitations of a static view of structural complexity (Maylor et al., 2008), which primarily emphasizes the technological dimension (hard aspects) as the main source of uncertainty in project content while overlooking the human aspects of the project. Additionally, the isolated identification

of complexity factors and criteria tends to overlook non-linear relationships. Structural complexity has received more attention from researchers, particularly under the rational paradigm, compared to dynamic complexity, which only began to emerge in the field of project management in the 2000s (Bakhshi et al., 2016).

Therefore, complexity remains somewhat of a black box. To delve into this black box, we draw on what is communicated, perceived, enacted, and transpires within the realm of the project as it is shaped, lived and experienced by the individuals involved (Blomquist et al., 2010; Cicmil et al., 2009). By conceptualizing the project as a dynamic socio-material network encompassing both human and non-human elements (Lessard et al., 2014; Smyth and Morris, 2007), we propose to explore the following question: How is social complexity shaped through the interactions and practices of inter-organizational actors in major projects?

Literature review

Complexity in context of large project

Inspired by the systems approach, early work (Baccarini, 1996; Gidado, 1996; Turner and Cochrane, 1993) identified the structural complexity as differentiation and interdependence. Williams (1999) extends this work by adding the uncertainty. Starting in the 2000s, authors introduced: contingent factors (e.g., Jaafari, 2003); dynamic dimension by integrating emergence, non-linearity, ambiguity, and autonomy in order to specify the system's behavior (e.g., Anderson, 1999); as well as the adequacy and preliminary exchange of available information (e.g., Mihm et al., 2003; Pich et al., 2002). Later, the literature on project complexity experienced a paradigmatic shift with the Rethinking Project Management perspective (Cicmil et al., 2009; Cicmil and Marshall, 2005; Cooke-Davies et al., 2007), which aims to integrate the socio-political dimension (e.g., power plays, conflicting interests).

In the same period, the Managing in Complexity trend initiated by the work of Geraldi (2008, 2007); Geraldi and Albrecht (2007); Maylor et al, (2008); Geraldi et al., (2011); Remington and Pollack (2007); Whitty and Maylor (2009) contribute to describing the trajectories of complexity from a subjective perspective. The underlying idea is that the complexity lies in the observer's perception based on their role in the project rather than in the structure or behavior of the system (Mikkelsen, 2020). It represents a starting point for situating the present paper which attempt to explore new perspectives to open the black box of the social complexity.

Further studies on project complexity are needed to enrich the understanding of the dynamic nature of complexity in relation to the continuously changing environment and evolving understandings and constituents of complex systems. It is necessary to go beyond the deterministic view and explore the roles of project actors (Geraldi et al., 2011). In this article, we explore the hidden facets of social complexity by drawing from the socio-

material perspective, in particular the work of Callon and Latour on heterogeneous networks dynamics.

Perspectives in understanding complexity

Actor network perspective

Without attempting to cover all aspects of Actor-Network Theory (ANT), our focus is the network. Callon and Latour employ this concept to address the crucial micro-macro distinction within social theories (Latour, 1996, 2002). Networks describe various assemblages of both humans and non-humans (objects, artifacts, discourses, etc.). The material was traditionally considered separately by conventional approaches. The attributes and characteristics that classify a network as large or broad hold little significance. What matters is whether the network endures over time, remains maintained, or exhibits intense connectivity (Latour, 2007).

Using ANT to explore project complexities is becoming more widespread. Sage et al, (2011) suggest ANT as an alternative approach that considers the role of nonhumans in influencing practitioners to inscribe, respond, and stabilize project complexities. The literature highlights the relevance of ANT in capturing the dynamics and emergent properties of the phenomena being studied by incorporating the perspective of heterogeneous networks (Florice et al., 2014; Pollack et al., 2013; Sages et al., 2011). It has the potential to expand the project management research beyond the traditional approach focusing on project content and generic, standardized techniques (Cicmil et al., 2009; Linde and Linderoth, 2006). More specifically the concepts of network and agency for example are appropriate for practice-based research that aims to produce the realities of dynamic, interdependent; emergent; multilayered complex projects (Cicmil et al., 2009; Sages et al., 2011). Thus, this perspective might offer a complementary pathway to interpret and generate detailed narratives about complexities while considering the importance of interconnections between human actors and material (Sage et al., 2020).

Conceptual framework

We present this conceptual framework by leveraging the theoretical foundations of ANT. We used framework for reflection and as a theoretical foundation for conducting our research. Further discussion on this framework will be presented in an upcoming contribution.

A major project is initiated with a proposal that does not necessarily guarantee the deliverable. It is more of a complex and less structured process based on social interactions (Flyvbjerg, 2014; Samset and Volden, 2016; Williams et al., 2019). Major projects may not succeed in attaining novelty and uniqueness, as the concept might have been previously

examined and discussed (Aubry and Lavoie-Tremblay, 2018) but which has not been approved for various reasons (e.g., lack of expertise, media leaks and opposition, high costs, etc.). Hence, it is essential to consider the historical context as an ex-ante element (Bredillet, 2008; Tsoukas and Chia, 2002). As illustrated on the left side of the following figure, the project's history also reflects the relational relationships between the organization and the actors in a multi-project situation. The background is not known by all the actors and may remain tacit.

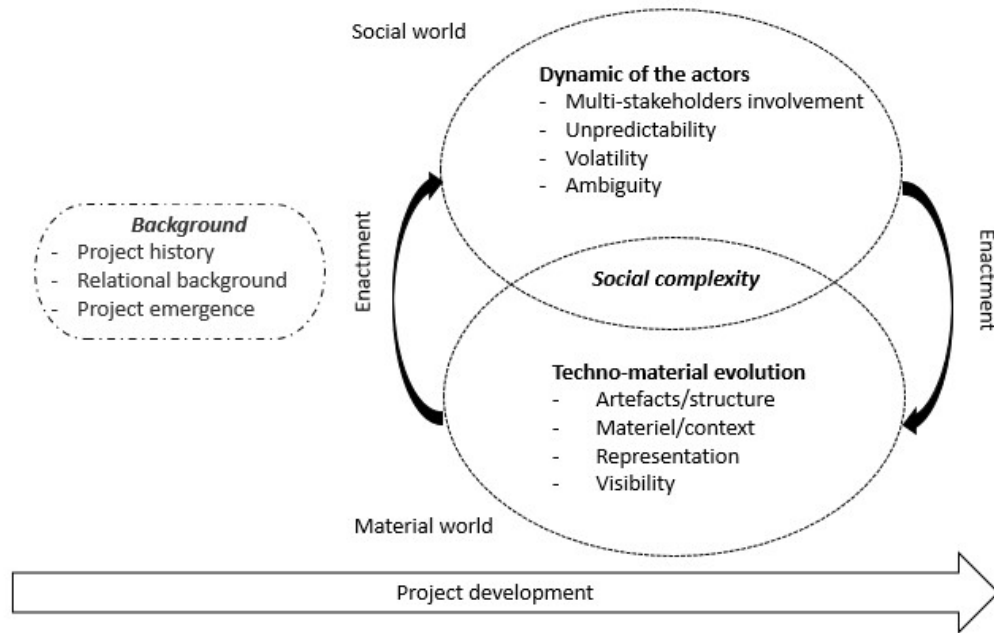


Fig.1: Conceptual framework of social complexity in the context of major projects (authors, 2023)

For example, the interactions between the project owner and the actors (internal and external) can be built on solidarity and trust. These relationships make it possible to build social capital (Bourdieu, 1980). However, they are not always positive; they can give rise to unresolved controversies arising from contradictory interests, unfulfilled expectations, contradictory visions, or unaligned perceptions, etc.

The social world is represented by the dynamics of the actors. We focus here on multi-actors' intervention, unpredictability, perception volatility, and ambiguity. These elements have been identified drawing on the socio-organizational complexity (e.g., Cicmil et al., 2006; Cicmil and Marshall, 2005). Moreover, these elements represent significant challenges faced by practitioners (Söderlund et al., 2017). They reveal diverse skills,

knowledge, cultures, practices, and approaches that evolve in ambiguous situations characterized by power asymmetry. (Denicol et al., 2021; Matinheikki et al., 2019).

Secondly, perceptions are volatile, as they change according to the situation. For example, when the project leader leaves, new visions of the project are formed, and new information and norms are introduced. Finally, stakeholder unpredictability is a dynamic dimension of stakeholders, due to uncertainty and lack of information in the pre-project phase (Edkins et al., 2013; Samset and Volden, 2016). This influences the process of identifying and classifying stakeholders (Atkin and Skitmore, 2008).

The social world interacts with the material world through an enactment process, and their dynamic interactions reflect the space of social complexity. ANT suggests that the relationships between human and non-human actors contribute to the emergence of networks, which can be unpredictable and impact the structure of a project. The material world encompasses the evolution of technology and materials, including the representations that are produced and utilized (videos, maps, databases, etc.). They play a role in the sociotechnical network, contributing to a range of actions and emotions (Comi and Whyte, 2018; Whitty, 2010).

Research design and descriptive case

Methodology

This research uses a qualitative approach based on the multiple case study (Stake, 1995; 2013). We drew on the principles of the grounded theorizing (Charmaz, 2014). This method offers the flexibility and possibility of bringing out theoretical concepts grounded in the empirical data through an iterative process. This iterative logic facilitates the targeting and reorientation of interviews as needed. This flexibility promotes a circularity within the analysis process that is not existing within the sequential and linear processes of other analysis methods.

Data collection

Within the first organization (ENG, energy sector), two major projects were selected. The second organization (TRA, transportation infrastructure) had one project selected. Both organizations are public and based in North America. The selection was based on a non-exhaustive list of criteria related to homogeneity and heterogeneity (Eisenhardt, 1989) derived from the conceptual framework.

Data was collected from three sources: a) Individual interviews b) Non-participant observations c) Internal and public documents, as well as press materials (e.g., press releases, impact studies, project presentations, internal complexity assessment grid, maps, visual simulations).

A total of 42 hours of semi-structured interviews were conducted with various profiles (e.g., table 2). An initial interview guide was developed based on the conceptual framework

and consisted of approximately 15 questions. The duration of each interview varied between 60 to 75 minutes. While the same interview guide was used, the questions were adapted according to the expertise of each profile (engineer, planner, public relations, architectural supervisor, telecommunications supervisor, security manager, etc.). Additionally, non-participant observations were conducted to further enhance the validity of the findings through triangulation (Merriam, 1998). The table 1 provides an overview on the three selected projects.

Case studies criteria selection	
Homogeneity criteria	Organization with a practical culture in project management (at least 5 years)
	Project with a social complexity perceived: various stakeholders (internal and external); Projets avec une complexité sociale perçue : intervenants multiples, one or several actors linked to a high level of risk; conflict situations; unpredictability; important social issues.
	Project life cycle: development and execution
	Cost and scope, 10 M\$ CA and up (this criterion is variable, it has been discussed with the organizations according to their internal guidelines)
Heterogeneity criteria	Diversity of purpose between organizations (legal status, industry or activity sector, variation in economic purpose)
	Nature of project (e.g., major infrastructure, consumer and transformation project).

Table 1: project selection criteria

Project	Complexity level	Interviewees	Observations
ENG 1	High	16	Weekly follow-up meetings Construction site visits (22h30mn)
ENG2	Average	13	Monthly follow-up meetings workshops Meeting with the public Public Hearings (19h)
TRA	High	14	Monthly follow-up meeting Work sessions (simulation of meetings with the public) (5h30min)
		Total = 42	Total = 47h

Table 2: number, profiles of respondents and duration of observations

Data analysis

A pre-analysis began more intuitively with the first interview conducted. More specifically, we took notes of ideas and thoughts that came to mind instantly as the interview unfolded.

Each of the interviews was replayed, transcribed, and organized in the Nvivo (12, 2018). This tool facilitated the ideas development and the memos writing. The coding process consists of two main steps: initial coding and theoretical coding (focused coding) (Charmaz, 2014).

Upon rereading the interviews, observations and documents, the initial coding was done line by line, to make sense of the data. Then, an initial list of subcategories assigned to the first project analyzed was generated (ENG1). The subcategories mention the beginning of conceptualization and linking categories. This list was progressively refilled with codes and subcategories from the other two projects (ENG2 and TRA). The second step is focused coding which emphasizes the most relevant initial codes, allowing a certain direction to the analysis toward theoretical codes. In the findings section, even if there are no extracts from observation notes/documents, this has always been present in the analysis and allows precision and reliability of the data.

Case description

Project ENG 1

Project ENG1(launched in 2015), with a budget of 1 G\$, aims to address the need for energy transmission from production centers in the north to major urban consumption centers in the south. The construction phase was scheduled for 2019, with an expected completion time of two years (2022). However, due to the pandemic situation, there have been changes to the project timeline. According to senior management and interviewees, this project is considered complex from organizational, environmental, and social sides. The multidisciplinary project team, led by the project manager, coordinates the efforts of various stakeholders in areas including design engineering, construction processes, environmental considerations. However, this project poses challenges for the project team in terms of social acceptance and integration into the environmental and social context.

Project ENG2

The ENG2 project (launched in 2018, 375 M\$) is a response to the increasing energy demand. It is part of a broader infrastructure plan aimed at modernizing the facilities. This project has undergone many changes in the definition and technical requirements driven by the owner revision aiming at ensuring better facilities. As a result, new public consultations were conducted from May 2019. Extensive discussions were held with the community to ensure a thorough analysis of the situation. The presentation of various scenarios was planned for 2021. Other communications are scheduled to start in June 2022. As acknowledged by project teams, as well as local and regional actors, the complexity lies not in the technical aspects but rather in the environmental and social aspects of the project.

Project TRA

It is an operational requirement aimed at redeveloping service facilities by addressing capacity issues. Launched in 2017, the construction started in 2017 and ended 2 years later. TRA is part of a strategic plan of optimizing and increasing facility capacity. This project

was budgeted at 13M\$ excluding the approved plans and specifications budget, bringing the total cost between 16M\$ and 20M\$. TRA complexity is perceived in terms of stakeholder involvement and management. A risk analysis was also performed (according to the internal directive, it is performed for 2M\$ projects and more). This analysis includes high probabilities of risk occurrence related to design, procurement, and implementation elements.

Findings

Three theoretical themes were identified: 1) prospective complexity, 2) concurrent complexity, and 3) retrospective complexity. They shed light on the processes through which social complexity is constructed over time. In the following sections, we present their gradual development based on the empirical data. Each theme is presented along with its associated sub-categories.

1. Prospective complexity

Three sub-categories emerged: human unpredictability, plurality and variance of perceptions, and anticipation. They are situated in a temporality specific to the project's prospecting.

1.1 Human unpredictability

When respondents discuss social complexity aspects, they mention human unpredictability as a major aspect. They associate it with unforeseen actors, the difficulties related to identifying and recognizing in an accurate way the actors who will be involved, concerned, engaged, or affected by the project:

And... it is also certain that we expect there to be public hearings, and we will probably have stakeholders who are not necessarily satisfied with the project and will come back. Perhaps there will be new ones as well, who will come? Who have never, ever raised their hand regarding the project. [Eng, ENG1].

The unforeseen actors (local community) whose expression of their opinions is likely to disrupt the process of legitimizing the project, represent a realm of human unpredictability. It involves discussions and arguments among the actors involved in critical events that determine the project's progress.

The project actors acknowledged that unpredictability evokes a range of emotions, including fear and apprehension. This is particularly true for those who encounter novel situations like public consultations or negotiations. These emotions are not perceived as exclusively negative or positive; rather, they appear to influence the team's motivation and their capacity for self-regulation:

But it's very difficult to listen because we also become emotionally involved, I was talking earlier about the emotionality on one side and on the other, but we are also human, we work and we also become emotionally involved... [Program Management, ENG2].

1.2 Plurality of perceptions

Multi-actors' interaction is complex, but it is sometimes addressed as a cooperative opportunity to question critical topics, balance project aspects, and take advantage of pooling various expertise:

I am personally in favor of genuine cooperation between us, but it depends on the situation. There are project managers who adopt the mindset of "the fewer people involved, the fewer problems." They are more accustomed to handling things on their own and tend to exclude specialists from various stages. On the other hand, I prefer to involve people more extensively, allowing them to truly experience and contribute to every step. I find this approach to be more engaging and rewarding. [PM, ENG1].

Project teams avoid multiple interventions to reduce conflict and tensions risk. In the ENG1 project, tension among project members escalated due to varying interpretations of the impact study results. The data and observations generated a range of different perspectives and divergent views on the risks involved within the project team. Some individuals advocated for transparency and pushed for immediate publication of the results, while others approached the situation with a more cautious mindset, emphasizing the need to review the results in light of the associated risk factors before making them public.

One issue is the localized mitigation measures, which aim to address the noise problem in case there is a significant disagreement between us and the workers. The perception of noise differs between us, as service officers, and the workers. We are not accustomed to working in an environment with constant noise, whereas it is part of their daily routine. The constant noise affects us as it hampers our ability to concentrate on our tasks. They may not fully understand the reality of our work and the challenges we face. [Eng, TRA].

1.3 Anticipation issue

Anticipation issue refers to the tension between the analytical aspect, which involves foreseeing the consequences of short-term decisions, and the adaptation which implies allowing flexibility to react appropriately to the project's evolution:

What I am interested in is the impact that the project has on our operations and the constraints that arise. Can we do something to improve this? Are there any tasks or other factors that will be affected by the project? The main objective is to ensure that the present and the future align with our needs and expectations, enabling our agents to be productive. [Owner, TRA].

Seen as a responsible precautionary measure in an uncertain context that needs to be analyzed and measured, anticipating social risks, which have direct impacts on costs and

timelines, adds to the complexity due to the related tensions, such as between economic and environmental aspects.:

Well, actually, when it comes to choosing a solution, it's always about finding a balance that is never quite exact between the technical, economic, environmental, and social aspects [Communication, ENG1].

2. Concurrent complexity (real-time)

In real-time, the complexity is higher than the previous ones. This is mainly due to the increased involvement of the actors, their roles, power dynamics that evolves the social arrangement. The relationships can range from conflict and opposition to cooperation.

2.1 Manifestation of constraints

The participants mentioned the emergence of constraints, which is evident through the events of foreseen and unforeseen impacts. They highlighted the interconnectedness between technical, environmental, and social constraints, which gives rise to the emergence of new constraints and various issues. However, for some participants (as indicated in the excerpts), isolated technical issues are not considered problematic, as solutions can be predicted when the necessary means and resources are available to overcome technical challenges. Instead, the interaction between technical, social, regulatory, and temporal issues that appears complex to address and manage.:

When it comes to technical and engineering aspects, we are capable of speeding up and progressing quickly. However, when faced with social opposition and environmental constraints, we experience significant delays in our schedule...

But when it comes to designing a new framework to execute the project, we can accelerate the project to meet the deadlines from a technical perspective, which is quite unusual! It can happen, in certain cases, particularly when the situation is highly complex, but generally, it is rare for technical factors to cause project delays. [PM, ENG2].

These interactions redefine the possibilities and trajectory of the project, which can have a negative impact on its effectiveness in terms of speed and progress, as reflected in this excerpt: "On the other hand, when we are faced with social opposition constraints in the environment, we completely lose the schedule" [PM, ENG2].

Furthermore, spatial constraints increase concurrent complexity, especially when the project is represented through maps, photos, or visual simulations, which can elicit reluctant reactions from external actors.

2.2. Tensions

The project actors continuously experience tensions that arise from the interdependence between various dimensions of the project, such as the social and technical, environmental and technical, and regulatory and environmental aspects. Likewise, the tension between client requirements and the project execution reality, as well as between current and future

projects in a multi-project context. Additionally, tensions exist between the project objectives and the actors' interests, and between short-term project temporality and long-term temporality of institutional, environmental, and social actors.

These tensions evoke emotions such as compassion, empathy, and the desire to execute the project successfully. They also give rise to decision-making dilemmas for the project actors, particularly when they possess the capability and experience to recognize and identify the impacts of these tensions on the project's progress. For instance, when confronted with conflicts arising from different temporalities, priority is given to resolving them due to their effects on project timelines.

It's in our interest to do a good job, and to leave a good impact on the community, but also for the next team that will come by soon. Because, you know, people stay around for a long time ... [Public Relations, ENG1].

2.2 Emergency

It represents a contextual element that reduces the time between the return to prospecting and acting:

Because we are constantly bound by directives... Time is of the essence here. The organization operates in fast-tracking, truly. Therefore, we don't have the luxury of time to engage in this type of work (understanding client needs) ... It's always quite urgent. [Consultant, TRA].

Emergency (TRA) is experienced as inherent to the organization's activities, whereas in ENG1 and ENG2, the emergency context is viewed as a temporary requirement that demands heightened responsiveness and adaptability. Nevertheless, across all projects, the emergency context entails a diversity of situations and timeframes. It forms an integral part of the ongoing discourse among project actors, alongside evolving needs and conflicts regarding roles and responsibilities within the contractual framework.

3. Retrospective complexity

Three sub-categories were identified: reflexivity, revision and investigation challenges and issues. These are situated in a retrospective temporality (afterwards).

3.1 Reflexivity challenge

Looking back on previous project activities, reflecting on their own thoughts, actions and perceptions is a difficult challenge to overcome:

I believe there is more work for me to do internally to gain PM trust. The project engineer seems to have almost blind trust in me, but I don't think the PM is convinced. This makes me realize that I need to work internally to help them understand and gain confidence, as their current level of confidence is not high. [Eng, TRA].

However, ENG1 provides a success story. This project encompasses both populated and unpopulated geographical and social spaces, each characterized by distinct socio-economic

and political factors, resulting in a range of unique issues and considerations. The project actors faced challenges in navigating the interplay between these contextual elements and the project planning. Actors have raised questions about the public hearing effectiveness given the specificity of each context. The goal is to strike a balance between heterogeneous expectations, such as maximizing economic benefits and ensuring equity. The team's commitment to "doing the project well" drives their reflective mindset, seeking improvement and successful integration of the project.

We aim to achieve success of a project that is well-received, as it sets the stage for future projects. We place great emphasis on ensuring a positive reception of the project within the community, as it paves the way for future opportunities. [PM, ENG2].

3.2 Revision challenge

The complexity arising from retrospection becomes evident as a challenge in revising past actions. Project actors face the task of reevaluating and modifying their previous decisions and activities. This challenge is further intensified by the inter-project dynamics:

Everything we had put in place to promote social acceptability. It may not be completely understood there... so we are questioning ourselves, should we go back to them (external actors)? because there are some who are no longer informed, but we will still inform them, that's what we will do. So now I am analyzing this. We can find a way to do it, we are considering it. [Public relations, ENG1].

Thus, project actors become aware of the dysfunctions and difficulties within the project, which are potentially due to divergent interpretation and understanding of the project content.

3.3 Investigation challenge

Project actors are involuntarily involved in a challenge of examining the previous occurrences and significant events of relational histories (between organization and external actors) that have occurred in the past as reflected in this excerpt: "... there are things that happened in '95 that are still being discussed today" [Public Relations, ENG1].

In order to understand the project context and requirements, the project team must navigate a challenging history that resurfaces after more than 20 years. As a result, the team relies on their resilience to incorporate this historical knowledge into the current context, shaping both the organizational memory and the experiences of the project actors.

It was very hard, very hard. Because I'm... quite stubborn, I held my ground at the risk of not having friends, but we couldn't really put the result in the study ... we talked about this study... people were experiencing stresses, and we announce that we are doing a follow-up and so the study will be available later. We managed it by saying that there is a risk [Environment, ENG1].

The unpredictability of these situations requires adaptation and past events updating in present project practices. The project team must thus deal with a new reality and new expectations whose decision-making activities are changing. All the findings discussed are integrated in the following figure:

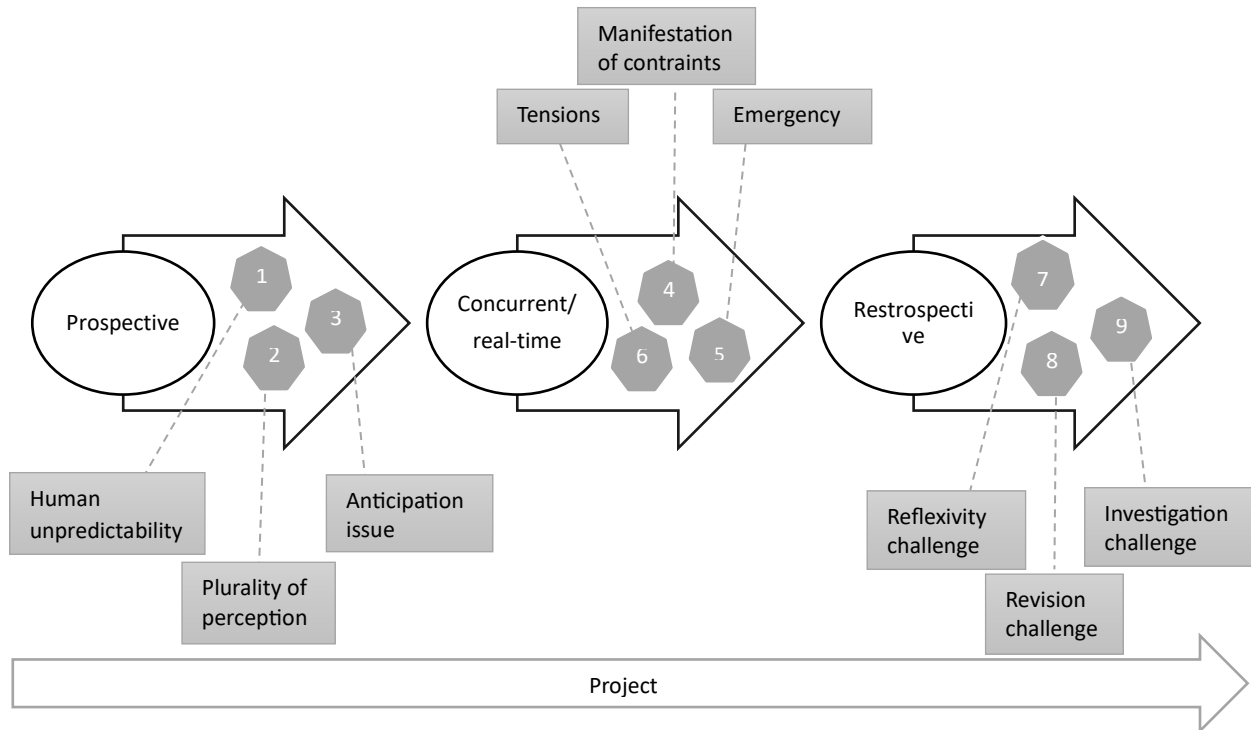


Figure 2: social complexity process within major projects

Discussion

The findings reveal how social complexity unfolds within project-network actors through three temporal modes. Their intensity depends on the interaction dynamics and the arrangement quality between project actors including the project teams, the material used, the knowledge produced, etc. Defining complexity objectively and comprehensively, as well as establishing means to assess it, is inherently challenging. Therefore, a subjective and constructivist approach is suitable for understanding this phenomenon (Pitsis et al., 2018; Williams et al., 2012). We do not aim to propose unanimous definitions of project social complexity components. Instead, by closely examining the micro practices of the three projects, we suggest a new socio-material conceptualization of major project complexity. The findings reveal tensions related to the plurality of perceptions regarding constraints of diverse nature. This allows for an understanding of the ambiguities, unpredictability, and emergence generated by network interactions and how the configuration of the project's network takes shape, evolves, and changes according to the orchestration of the past, present, and future temporalities. We support the role of tensions

and paradoxes (DeFillippi and Sydow, 2016; Schad et al., 2016; Smith and Lewis, 2011) as an inherent force in shaping the project-network and materializing social complexity.

Our findings indicate that social complexity is not an inherent property of major projects but rather an evolving construct shaped by the conflicting interests and representations of actors. These actors are embedded within networks of constraints and technical possibilities that are continuously renegotiated. Social complexity, therefore, manifests itself in various dimensions and forms due to the diverse ways in which project actors and events interact at different stages throughout the project's life.

Also, social complexity is not a pre-existing state that exists independently of the project, but rather a social construct that emerges within the project's network configuration. Complexity is seen here as a process which means that it changes and can be affected by experiences and arrangements. This endogenous nature of social complexity makes it specific to each project. For example, the actor's configuration and their interaction (project sponsor/client, project manager, external actors) - prior to the project technical definition - influences the project development and execution dynamics by shaping the solutions selection. This arrangement might have positive or negative implications on social complexity. However, if the arrangement among actors occurs late in the process, the risk of divergent effects emerging is high as oppositional behavior (local community).

In practice, despite the maturity in managing major projects, the organizational context of the three projects lacks a framework to understand, detect, evaluate, and manage complexity, which the case for many organizations (Shenhar and Holzmann, 2017) and largely depends on mental frameworks that perceive complexity (Mikkelsen, 2020; 2021). However, these organizations (ENG-TRA) have established formal systems to reduce the effects of complexity on project progress. For example, the identification, quantification, and mitigation of risks, planning, control, and communication. However, these responses do not fully address the uncertainty and human unpredictability, thus complexity remains problematic (Shenhar and Holzmann, 2017). Furthermore, findings reveal that when confronted with emergence and change, which characterize the evolving nature of social complexity over time, the capacities of adaptation, openness, and collaboration are acknowledged as relevant but difficult to put into practice due to challenges including learning difficulties, the inability (utopia) to meet all stakeholder demands, political issues, and costs. This resonates with the Wiewiora and Desouza (2022) discussion on the diversity of stakeholder preferences that fuel paradoxes such as the inclusion/exclusion of external stakeholders in decision-making.

Theoretical contributions

Thus, we contribute to the current of subjectivist complexity (e.g., Maylor et al., 2013; Mikkelsen, 2020; 2021) by enriching the diversification in the understanding of social complexity over time. Our vision aligns with the current trends in project management (Cicmil et al., 2006) and theoretical pluralism (Denis et al., 2007; Geraldi et al., 2008; Söderlund, 2011). We try to shift from complexity instrumental approach to complexity

socio-material and temporal approach. Few empirical studies have explored what actors do when engaged in complex situations to gain a deeper understanding of these dynamics. Moreover, this research can inform the temporality literature which is mainly conceptual (Brookes et al., 2017; Söderlund, 2013). Empirical evidence also bears on constructed and evolving tensions by revealing for example: the plurality and variance of perceptions and links to conflicts, which could contribute to the theory of paradoxes.

Managerial implications

This research is based on practice view that encourages proximity between project-organizations reality and academic research. Rethinking project management call for a shift from theory of practice to theory in practice by anchoring the research in the reality of the projects as lived and experienced by the actors (Cicmil et al., 2006). The findings provide valuable lessons for practitioners involved in the management of major projects and engaged in designing integration and organizational coordination methods, practices, and tools. These lessons pertain to the definition, assessment, and management of project complexity. Moreover, they highlight the importance of promoting reflexivity among practitioners in order to better understand the challenges and realities of social complexity. This can enhance their ability to identify and develop new project trajectories.

Conclusion

Limitations and future research

This research is based on a multiple case study appropriate for exploration. However, it does not allow the systematic generalization of results, but rather the generation of common patterns and their particularization by offering attention to the local situation (Stake, 2013). Furthermore, the study's scope is limited to a small number of cases (3). However, this limitation is mitigated by the inclusion of two distinct organizations operating in the energy and transport sectors. Additionally, the geographic north American context in which these projects took place may introduce certain limitations, as cultural factors can influence processes, practices, and institutional frameworks. Therefore, the findings should be interpreted cautiously considering the potential cultural influences.

The issue of respondent availability limited the opportunity to collect data over a longer period. Therefore, it is recommended to consider a longitudinal study to better capture the richness of data at different project phases and track its evolution over time. Future research could explore each of the social complexity mode in each project phase and extract the practices adopted to deal with as mainly related to learning. A further direction for future research is exploring the dynamics between the arrangement of project network actors and the organizational structure (at the program and portfolio management level) to further delve into the change initiatives generated and captured by the organizational field.

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