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Embeddedness and actors' behaviors in large-scale project lifecycle: Lessons learned from a High-Speed Rail project in Spain

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Abstract

Despite wide-ranging research on large-scale infrastructure project performance, little is known about the role that project public institutional context and project owner's response capability plays in the governing process. Building on a theoretically driven approach and a case study, we first established a set of propositions, and then substantiated this set through empirical illustrations. This study investigated the multi-actor Madrid–Barcelona high-speed rail line (HSL) project (1990–2017) with the use of social network analysis supplemented by qualitative evidence. The findings show that actors' behavior is affected by the project public institutional context, coupled with contractual commitments. A closer examination of the data found two factors that drive the escalation dynamics: (1) the timing mismatches—a ubiquitous feature of public sector project owners' organization—leading to the incapacity to influence governance during the project front-end and (2) owners' passive behavior during implementation. From the management perspective, an active owner with high project response capability is necessary for effectively interacting with contractors, and for selecting and managing both contractual and trust-based governance mechanisms effectively. Based on the findings, the authors offer theoretical and managerial implications for promoting the effectiveness of owner-contractor collaboration in large-scale infrastructure projects.

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Introduction

Large-scale infrastructure projects perform poorly in terms of cost and time (Flyvbjerg 2014), particularly in the public sector (Ling and Tran 2012; Ling et al. 2013). Dynamic (inter-)organizational contexts and complex processes characterize these projects (Gemünden, 2015; Chen *et al.*, 2017; Zheng *et al.*, 2018; Havenvid *et al.*, 2019). They involve diverse public and private actors over a specific period, which often leads to uncertainties, high transaction costs, and opportunism throughout the large-scale project lifecycle (Verweij *et al.*, 2015). Hence, large-scale infrastructure projects pose challenges in terms of managing procurement, design contracts, collaborative learning, and governance (Caldwell *et al.*, 2009; Caniëls *et al.*, 2012; Manley and Chen, 2017; Shi *et al.*, 2018; Liu *et al.*, 2019).

Many scholars have focused on addressing these shortcomings suggesting methods to improve the performance of large-scale infrastructure projects (cf. Zheng *et al.*, 2018, 2019; Li, Han, *et al.*, 2019). For that purpose, scholars have focused their attention on the team integration based on relational theory (cf. Cao and Lumineau, 2015; Wang *et al.*, 2019). To facilitate the inter-organizational collaboration among the parties involved, relational governance, trust and relationships beyond the single contract are often cited (DeFillippi and Sydow, 2016; Xue *et al.*, 2017; Gao *et al.*, 2018; Zheng *et al.*, 2018; Qiu *et al.*, 2019). Extant literature has identified factors that hinder and promote inter-organizational collaboration. For instance, it has validated the positive relationships between the governing mechanisms and the overall project performance (see Li, Han, *et al.*, 2019). It has addressed multiple moderating effects of inter-personal relations and behavioral attributes, which were captured primarily through survey-questionnaires. However, it seems that few scholars have explored the governing process, and actors' behavior in practice and throughout the project lifecycle (cf. Sanderson, 2012). This is a critical gap, particularly when considering that the inter-organizational relations are intrinsically unstable and that the effect of governance mechanisms on project actors' behavior during the project lifecycle changes (Caniëls et al. 2012; Zheng et al. 2019). Indeed, there is a need for longitudinal empirical research, with a focus on project lifecycle, to investigate the project actors' behavior and the relational governing activities – at a substantial and more profound level of team integration: the network level.

The inter-organizational collaboration and the overall large-scale project performance can be affected by important contextual conditions (see Xue *et al.*, 2017). The first is the extent to which the organization is centered on the project delivery, and the second condition involves the public project

institutional context (cf. Jacobsson and Linderoth, 2010; Qiu *et al.*, 2019; Zheng *et al.*, 2019). Regarding the first, recently, Winch and Leiringer (2016) – relying on government reports and other studies – showed that only a small proportion of infrastructure project delivery problems are caused by either supplier incompetence or externally generated risk events. According to them, 'overwhelmingly, the failures can be attributed to the public sector owner' (Winch and Leiringer, 2016, p. 8). Hence, they suggest a need for a 'strong project owner' and imply that the project owners, in general, lack the capability to identify and acquire operational generated knowledge that is critical to the large-scale project performance. The second, public project institutional context implies, for example, 1) the characteristics of procurement and project owners focus on the lowest-price tender policy (Ling *et al.*, 2013; Liu *et al.*, 2014). 2) the relations between project actors that are inclined by market-based interactions and are thus short-term focused (Dubois and Gadde, 2002; Doloi, 2013; Ling *et al.*, 2013; Manley and Chen, 2017), and 3) the project delivery method and types of construction contracts (cf. Rahman and Kumaraswamy, 2008), etc.

Given this backdrop, we regard the concept of *governance inseparability* (Argyres and Liebeskind, 1999) as a promising starting point for addressing the two key contextual conditions influencing the inter-organizational collaboration. The fundamental idea of governance inseparability underlines that the governance choice is actually more particularistic than the current discourse presents. In other words, by focusing on characteristics of isolated transactions seems insufficient to explain the large-scale project performance. Following Argyres and Liebeskind (1999, p. 49), contractual commitments play a key role and they should be discussed in context. Hence, the regulatory environment and prior contractual obligations made by an organization can limit its ability to differentiate or change its governance mechanisms in the future. Building on this reasoning, and other argumentative discussions underpinning institutional and transactions cost economics; we proceed to consider the context influence, in turn. We investigated the multi-actor Madrid–Barcelona high-speed rail line (HSL) project from the perspective of the project-owner organization (Adif). While the focus was intentionally placed on the project-owner, contractors and supplier's perspectives have also been examined to have an informed view of the owner's response capability. We advance a small and suggestive set of propositions throughout the project lifecycle with which to seed future theorizing.

This study extended the existing perspectives described above by exploring the inter-organizational interactions and actors' behavior: 1) in the context of the regulatory environment in Spain,

which determines such interaction; and 2) sequentially, by discussing actors' behaviors throughout the project lifecycle. This approach enabled an explanatory power to the *evolving changes* regarding actors' embeddedness and their behavior throughout the project lifecycle. Project actors are viewed as embedded when they set relations in such a manner that can affect and be affected by other's behaviors and context. Therefore, we asked the following guiding question: *How does the regulatory environment affect the project actors' behavior and their governing activities in a large-scale infrastructure project, and how can public project owners deal with the opportunistic behavior of some of their providers?*

Apart from this introduction, the paper consists of four other sections. The next section provides the theoretical analysis, followed by a section addressing the research design. The subsequent section discusses the case analysis and findings, and the final section concludes the paper by discussing some of the managerial implications, study limitations, and suggestions for future research.

Theoretical Foundation

Large-Scale Infrastructure Projects and Actors' Behavioral Patterns during the Project Lifecycle

The large-scale infrastructure project lifecycle comprises two important stages: 1) the project front-end, which includes the project definition, pre-execution activities, and network structuring; and 2) the implementation, which consists of the execution and operation activities (Morris 2013). These project stages are dramatically different, since project actors engage in different influential activities, with the project actors' flexibility and the project owner's response capability being crucial (Aaltonen and Kujala 2010; Winch and Leiringer 2016; Chen et al. 2017). Project actors' operational flexibility emerges from the contract's capacity to accommodate changes without breaking under the strain of changing conditions (Ling and Tran 2012). In this study, we aimed to explain the regulatory environment and project actors' behavior in the two distinct stages of the project lifecycle.

Project front-end.

At the project front-end, large-scale projects garner attention from politicians and promoters alike. They both seek visibility, because a high profile helps them to be re-elected (the "political sublime," in the words of Flyvbjerg 2014, p. 9). Due to the political agenda, and the close bond with the election cycle (which is usually in four-year terms), large-scale projects' front-ends are characterized by a sense of urgency (Flyvbjerg 2014; Li, Lu, et al., 2019), which means that at the project-front end, project estimates

are “cooked”: costs are underestimated, and revenues overestimated, in order to show overvalued economic development with undervalued environmental impact (Flyvbjerg et al. 2003, p. 84). These issues, and the occurrence of multiple delusions in practice, are facilitated due to negatively affected stakeholder groups being “kept in the dark.” Particularly stakeholder groups that are not in a direct contractual relationship, e.g., local or non-governmental organizations concerned with environmental safeguards and the protection of the human rights of affected parties (Aaltonen and Kujala, 2010; Scott, 2012). The project front-end is inherently uncertain and, when reaching a project “go” decision, fuzzy political influences often create a “smoke screen”. Issues arise here often because budgets are often based on conceptual estimates for vague components rather than a detailed specification’s from properly planning and design. Therefore, we proposed the following:

Proposition 1—Project urgency, produced by powerful project promoters at the project front-end increases uncertainty and fosters a project degradation

Large-scale infrastructure projects involving government sponsors, rely heavily on formal governance—governance mechanisms such as rules and procedures that are known as “authority” (Caniëls et al. 2012, p. 114). This institutional regulatory regime has a strong influence on the progress and the governance of these projects (Chi and Javernick-Will 2011; Zheng et al. 2019), so the role of the government as both regulator and stakeholder is peculiar. Multiple dyadic relationships are formed, based on detailed contracts (Williams and Samset 2010; Edkins et al. 2013). In this context, both parties want to maximize their share of the contract. Under such conditions, a conflict of goals arises between the project owner, who seeks to minimize the total investment, and the contractor or provider, who aims to accomplish the task with minimum effort and obtain its share promptly (Floricel and Lampel 1998). Particularly in a public project context, however, the burden of this conflict tends to fall on the project owner, who seems to be “sandwiched” (Ning and Ling 2013, 2014). On the one hand, the project owner has to respect its principal—the government authority—which is driven by a political agenda and by the media (van den Ende and van Marrewijk 2018). On the other hand are the contractors, which may behave opportunistically. The project owner therefore has to deal with contingent issues streaming from this entangled relationship, known as “agency costs” (Floricel and Lampel, 1998). Multiple governance mechanisms can be used as safeguards against opportunistic behavior (Jap and Ganesan 2000; Caniëls et al. 2012; Zheng et al. 2019), but within public projects, unlike private ones, the project owner is heavily

influenced by the institutional environment—the meta-rules—and needs, at the same time, to maintain an arm's length relationship with contractors to avoid corruption (Ling and Tran 2012; Locatelli et al. 2017).

Existing research has stated that, at this stage, lowest-price bidding, reliance on long-term prequalification results, ambiguous contracts, and overreliance on subjective judgments invite opportunism (Doloi 2013; Shi et al. 2018; Le et al. forthcoming). Williamson (1979, p. 234) defined opportunism as "self-interested seeking with guile." Opportunism implies calculated efforts to mislead or confuse another party, based on incomplete or misrepresented information. On the one hand, explicit contracts cannot ensure that the contractors will reveal private information to facilitate impartial arrangements (Zhou and Poppo, 2010). For example, when not convenient, some contractors do not follow the meetings periodically for the joint activity planning to provide their input and moderate the project costs. On the other hand, the contracting system and the documents may be incomplete because of human bounded rationality, e.g., an incomplete contract or project document with fewer clauses or details that are not verifiable nor observable (Cao and Lumineau, 2015). Various studies have shown the negative impact of opportunism on inter-organizational relations (Rahman and Kumaraswamy 2008; Ling et al. 2013; Shi et al. 2018; Zheng et al. 2018), and on the overall performance of projects (Ke et al. 2015; Xue et al. 2017; Liu et al. 2019; Zheng et al. 2019; Caniëls et al. 2012). The problem is not only that the quality of the contract is deficient (i.e., that the documentation is not clear and detailed), but that it creates further avenues for opportunism in the next stage. Contractual loopholes, such as errors or ambiguous clauses, may lead to unforeseen rework, involving loss of efficiency, productivity, and time, as well as possible contractual claims and litigation (Lopez and Love 2012). Since some contractors know that the owner is vulnerable, they may lower their price to win the contract, expecting lucrative change orders based upon contract loopholes and subsequent claims to recover their costs (Rahman and Kumaraswamy 2008; Ning and Ling 2013; Shi et al. 2018; J. Liu et al. 2019). The issue of contract ambiguity or (in)completeness (i.e., legal tolerance and the latitude for speculation) is instrumental in causing adversarial relationships in complex projects (Pryke 2005, 2012). Therefore, we proposed the following:

Proposition 2—The greater the contract ambiguity, and the information asymmetry between the project owner and the contractors, the higher are the chances of opportunistic behavior

Implementation stage.

At the implementation stage, triadic and network relationships develop (Zheng et al. 2019; Verschoore and Adami 2020). In a public sector project context, these relationships are contractually-bounded and subject to institutional governing rules, which require competitive bidding (Henisz et al. 2012; Zheng et al. 2019). At this point, considering the large-scale project size and scope, the transaction volume is high (Williamson 1979). Hence, project owners must always assume some risks of governance inseparability. That is, the project owner will become constrained over time by the existing arrangements in place, which to some extent limits their scope and their strategic flexibility (cf. Argyres and Liebeskind, 1999). Nevertheless, recent studies have stated that the repetition and frequency of interaction between the project actors, and the consequences generated trust, also sustain the network relations (Chen *et al.*, 2017; Havenvid *et al.*, 2019). Relational capabilities and transaction frequency can be seen as the effect of inter-organizational learning through repeated interactions with contractors. Consequently, it is critical for owners' response capability to learn from previous project activities, in order to analyze, process, understand, and act on the information obtained (cf. Winch and Leiringer 2016). This includes being selective about contractors and their opportunistic behavior (Shi *et al.*, 2018; Liu *et al.*, 2019).

Nevertheless, public project owners are generally passive throughout the project lifecycle: they fail to learn and achieve trusting cooperation with the contractors. Mainly because they rely heavily on external consultants and lack both contracting and relational capabilities (Winch and Leiringer 2016; Aerts et al. 2017). We link this lacking capability to the project owner's response capacity, which concerns the adaptive management of expectations in the context of unexpected, i.e., high uncertainty. As indicated earlier, during implementation, there is often much that is unexpected. Thus, being active is about the project owner's dispositions that shape their response capacity for learning, adapting, and acting accordingly. An active owner, demonstrates the capabilities to interact effectively with the contractors or providers, and is able to select and effectively use both formal contractual and trust-based governing mechanisms (Caldwell et *al.* 2009; Winch and Leiringer 2016; Zheng et al. 2018). In short, an active owner goes beyond traditional contract administration and established transactions. It addresses operational issues in-depth, i.e., relations and contractor's behavior with a greater sense of operational intent to avoid opportunism on the part of some contractors. Given that large-scale projects extend over decades, project owners based on the other parties' performance — such as contractors or suppliers'—

during their earlier phases in projects, can learn and process to analyse and act on the knowledge obtained in-site. So, we proposed:

Proposition 3— The greater the degree of the owner's passivity, the greater the missed opportunity for learning and the generation of trust, reducing value for money.

As Williamson (1996, p. 9) indicates, transaction cost economics concedes that comprehensive contracting is not a feasible option (because of bounded rationality). Yet it maintains that many economic agents have the capacities both to learn and to look ahead, perceive hazards, and factor these back into the contractual relation, thereafter to devise responsive institutions. Argyres and Liebeskind(1999, p. 54) adopted this view. They affirmed that it presents healthy tensions for the management, but that these tensions resolve more in favor of bounded rationality than in favor of foresight. In this view, in large-scale projects anticipating future hazards and opportunities seems almost impossible (Lenfle and Loch, 2010).

Given the above, active owner activities must take place during project implementation. In this stage, properly staffed owner's teams are important (Merrow 2011; Winch and Leiringer 2016). Besides, when the project proceeds to the implementation stage, some manipulation of the contractual loopholes becomes increasingly visible. The above implies that strategic misinterpretation may repeatedly occur throughout the project lifecycle and that some contractors' opportunism and the owner's passive role are integral to it (Winch 2013). In other words, the escalation dynamics are likely in this process. This issue is exacerbated since large-scale projects require financial resources (within) at all stages (Guo et al. 2014), often to meet internal performance targets. We assume that the decisions for financial resources are made in at least a bounded rational way and are not merely the result of random processes. However, when circumstances change in the process, the 'strategic misinterpretation' that precedes these decisions may restrict the project owner's response capacity. We therefore proposed:

Proposition 4—A deliberate strategic misrepresentation of forecasting outcomes enables the occurrence of multiple "delusions".

Research Design and Methods

In order to gain an in-depth understanding of the governing process and actors' strategies and behavioral patterns during the project lifecycle, we selected a longitudinal case study design (Yin 2013) in order to analyze a multi-actor project: the Madrid–Barcelona HSL in Spain. We used the case of the HSL

project to enhance our understanding of the developed theoretical propositions. The case study method was chosen for two main reasons: (1) it offered the opportunity to investigate processes in-depth and was widely accepted as suitable for gaining an understanding of a multidimensional phenomenon (Eisenhardt and Graebner 2007; Yin 2013); and (2) it afforded multiple sources of evidence such as, for example, direct observations, interviews, and document analysis, to improve the overall quality of the analysis and enable corroboration (Yin 2013). Our research strategy comprised both qualitative and quantitative approaches (Morgan 1998), aimed at different elements of the HSL project, including the institutional regulatory environment, public procurement legal implications, and the interplay of actors' in the context; hence, it involved an exploratory case relying on theoretical elaboration (Ketokivi and Choi 2014).

Case Description

The case study provided many examples of changing behavior, driven both by organizational politics and by adaption to project contextual changes. The major construction work of the project lasted for two decades (1990–2008); however, due to problems with contracts, and suspensions during 2009–2017, the project's network organization continuously rearranged the project's design and plans, redefining its scope. The HSL project ran from the early 1990s to 2009, and was ambitiously planned and designed to reach speeds of 350 km/h (≈ 220 mph). It was intended to connect the Spanish capital of Madrid with the city of Barcelona (649 miles/1,045 kilometers distance) in order to substantially replace the existing air traffic route (Report 2012). The project definition started in the mid-1980s and, on December 8, 1988, the Spanish Council of Ministers granted approval for the project. The project was co-funded by the EU and the Spanish government and was considered to be a crucial and prestigious project, since it connected Spain to the European high-speed rail network for competitive freight transportation, via the French border, from Barcelona. As the owner responsible for the management of the infrastructure, Adif divided the project work into three major sections (construction phases). The first section was Madrid–Lleida (443 kilometers), initiated in 1993–1995 and completed on October 11, 2003; the second section was Lleida–Tarragona (108 kilometers), which was completed in December 2006; and the third section was Tarragona–Barcelona (98 kilometers), which was completed in February 2008.

For its construction, 2,095 main contracts were awarded for €6.82 billion, with a total amount of tender for €7.55 billion, 38 complementary works contracts for an amount of €171 million and 9 emergency works for €239 million and whose final cost amounted to a a little under €9.00 billion, which

originates an average price of €14.4 million per kilometer, with a 31.4% deviation from the initially planned prices, due to contract modifications, complementary and emergency works, price reviews and additional settlements (Report, 2013).

Data Collection

Data was collected over roughly 20 years, drawn from the contracting database (exported from the owner's enterprise resource planning), semi-structured interviews, participant observations, and secondary data sources (e.g., audit reports). The qualitative approach involved data collection during two periods, under the supervision of the third author, which allowed for a longitudinal view of the project over the entire lifecycle. We summarize the research data in Table 1. The process steps described here were more iterative than linear in character, and the main baseline moved sequentially, but there were often interactive steps.

[INSERT TABLE 1 ABOUT HERE]

The quantitative approach, first involving the use of social network analysis (SNA), measured the structural properties of the multiple contract packages of the HSL project, tracking change patterns and different contract flows. Second, we used a Bayesian approach to exploit the quantitative data and address areas of uncertainty stemming from actors' behavior in the project setting. Its application enabled the owner's response capacity to be assessed vis-à-vis the selected provider. We will return to this point and explain the measurement in greater detail in the following section.

The data involved, for example, information about the tendered amount, the awarded amount, modifications to time and financial information, delivery dates, initial estimated duration, date contracted, contract winner, etc. Data formatting was necessary, so the data was imported into an SQL platform, which enabled querying and checking of the contractual flow, identification of relations from the beginning of the study, and their evolution during the project implementation. The dataset supporting the quantitative analysis covered more than 5,000 contracts relating to over 4,000 sub-segments of the HSL. It is worth noting that a single contract could apply to many sub-segments. The typology for those contracts covered eight different topics in different phases, from design to construction and maintenance. When considering the whole portfolio, the timespan extended from September 1996 until December 2016 and involved more than 1,700 different contractors. Information regarding the awarded delivery dates and budget was also

provided at the contract level, in such a way that deviations in both schedule and cost could be analyzed by contract level, time period, segment, or contractor (see Fig. 1).

[INSERT FIGURE 1 ABOUT HERE]

Additional evidence, such as formal time-based progress reports and named certifications of work performed, were also available. These certifications involved more than 80,000 references from seven different classes, covering the regular and final certifications, but also non-regular ones. An additional set of incidents was recorded and analyzed, covering more than 30,000 issues relating to the different contracts. 81.7% of the total project costs originated from 666 works implementation (construction) contracts that had been awarded for an amount of €5.40 billion, with an initial saving of 10% on the bid price. However, as a consequence of the modifications of the contracts, the formalization of 34 contracts for complementary works and 9 emergency works, the price reviews and the additional settlements, the total cost of execution of the works amounted to €7.32 billion, 35.5% higher than the award price of the original contracts. In addition, 555 files for extensions and term extensions were processed, for an average period of 4.5 months per file. Table 2 shows the number of contracts and incidents throughout the project implementation. During the project implementation, 69 change orders were formalized, and 14 contracts for complementary works and 8 for emergency works were awarded, which, together with the price reviews and additional settlements, raised the total cost of the works initially contracted to €3.03billion, which represented an increase of 49.6% (Report, 2013). Hence, the initial saving of 9.2% in the bidding price of the contracts ended with a cost increase of 35.8% compared to what was originally planned.

[INSERT TABLE 2 ABOUT HERE]

Figure 2 shows the number of contracts awarded per contractor, and their type. 33% of the contracts were for execution of works, 30% for technical assistance, 13% for supply contracts, 3% for services, 16% corresponded to agreements and spending files and the remaining 5% were minor contracts. As can be seen in Fig. 2, repeated collaboration exists, as the same organization plays different roles in the HSL project, e.g., as a contractor, and at times as a supplier of specific elements of the project. Besides, Fig. 2 partly illustrates that the construction of infrastructure involved a large network of contractors and suppliers. However, more than 74% were awarded to approximately 10 contractors — if we consider the consortiums UTE [in Spanish: *Union Temporal de Empresas*] among these 10 organizations. That is, the 10 UTEs were present in almost seven out of every ten euros' worth of work contracted.

[INSERT FIGURE 2 ABOUT HERE]

The available dataset provided fine-grained information, enabled a detailed analysis, and was useful for comparing and contrasting the qualitative evidence (Pryke 2012). The overall collected data was organized according to themes (e.g., the institutional environment, public procurement law, structural and relational coordination, contracting information, etc.). These themes were further analyzed to identify patterns of activities during the project lifecycle. The rich data and the project lifecycle view, we argue, effectively served and complemented our analysis.

Case Analysis

Relational structure of the HSL project.

To identify the actors' behavior patterns and their influence within the HSL project it is worth analyzing the centralization of meaning for the whole network. Hence, the focus is on what Pryke (2012, p. 91) referred to as the *degree of point centrality*. Actors' centrality refers to the node that describes an actor's importance in the network. Centralization, in general, relates not to the relative prominence of the points, but to the overall compactness or integration of the network, as reflected in its shape—an eigenvector. Thus, following Pryke (2017, p. 18), the actor's prominence or centrality is indicated by the size of the node, so "nodes which are large relative to other nodes indicate prominence." The measurement of the degree of points' centrality is based on the analysis of contractual relationships and information exchange in the network. It has been argued that the centrality value reflects both authority and power in the network (Wasserman and Faust 1994; Verschoore and Adami 2020); however, high centrality in a contractual project network is no guarantee of control over events or the activities of other actors in the setting (Pryke 2012, 2017). Pryke (2012) suggested that the extent to which centrality affects the degree of control and authority in the network is contingent on the structure of the whole network, primarily on the extent to which the central actor can influence groups and the network as a whole. Thus, centrality relating to actors' prominence needed to be considered for the main actors; particularly, the effects on these actors' behavior, which was influenced by the procurement strategies and the institutional environment. Consequently, we highlighted the prominence of the project owner in the contractual and information exchange network of the project. In the analysis that follows, basic and relevant formulae, relating to each SNA key concept, were instructive and useful (see Wasserman and Faust 1994; Pryke 2012).

[INSERT FIGURE 3 ABOUT HERE]

Figure 3 shows the HSL projects contractual flows, when a construction segment is considered. It outlines the contract-by-contract relations of the owner and the direct/indirect relations with contractors and other suppliers based on the lump sum contract type. Such relations underlined the coordination structure of the HSL project as a result of competitive procurement logic and a dyadic mind-set (cf. Verschoore and Adami 2020); however, Figure 3 also shows some relational structures. Since we tracked these relationships through the contractual database, the interfaces within the UTE packages were the responsibility of the contractor consortia and unknown to the public sector owner. Considering that this data referred to the implementation stage, it was expected that greater cohesion would be achieved at this stage (Steen et al. 2018; Verschoore and Adami 2020). In the following, Figure 4 shows the HSL project information flow.

[INSERT FIGURE 4 ABOUT HERE]

As can be compared (see Fig. 3, and 4), the contract conditions did not reflect the information flow patterns, or, consequently, an actor's centrality; hence, the point or degree of centrality was relatively high since Adif had a relatively large number of primary connections. The differences in an actor's centrality across the relational structure of the contractual network and the information flow highlighted what might be referred to as a 'lack of correspondence in forms of governance within the inter-organizational network' Pryke (2012, p. 93). The figures above show that the HSL project was relatively well connected, considering the high level of contractual compactness, mainly because of Adif's high degree of centrality. However, even though Adif related to other actors by the shortest possible routes, few actors were connected to an actor other than Adif. More numerous contractual links, therefore, provided more opportunity for contractual disputes (cf. Pryke 2012). Collaborative procurement, by contrast, has fewer contractual links, since it focuses on a relatively small number of influential actors (Pryke 2012; Verschoore and Adami 2020).

Having considered the compactness of the HSL network, we directed our attention to the centrality, which showed that the network was rather owner-centric, with an eigenvector value of 0.828. Considering the project owner's centrality, a value greater than 0.50 was unsurprising, reflecting the classic "star" structure of contractual relationships see Table 3 (cf. Pryke 2012). The high centrality, we argue, was closely related to the fact that the Adif organization managed the project and was considered to be the future operator of the HSL. In addition, Adif entered into direct contracts with specialist suppliers

and all-important providers with key roles in the project; thus, Adif was influenced by the need for unambiguous contractual relationships, which led to the almost exclusive use of dyadic contractual relationships. Anecdotal evidence gathered during the interviews indicates that Adif was understaffed and lacked monitoring capabilities "in the field," so Adif experienced a large number of variations under the terms of the contract.

The above shows that the project owner (Adif) adhered to a traditional hierarchy of contractual conditions, which was reflected in its contractual centrality. According to Pryke (2012, p. 75), "comparison of the centrality values in contractual, incentive and information exchange networks, for a given actor, provide a measure of the maturity of a particular actor role within a procurement approach." Consequently, it would have been wrong to conclude that a high level of centrality within a classic star network is effective for monitoring and information processing.

The network had to be critically analyzed in terms of incoming and outgoing information or payments (Pryke 2012). It was useful, at this point, to turn our attention to the in-degree/out-degree data relating to the project owner. In-degree refers to the number of connections where information is incoming (i.e., the changes reported by the contractors and third parties) and out-degree refers to the opposite. An examination of this data helped in understanding whether the information was weighted toward the receipt of information relating to variations by the (sub) contractor. Particularly, it was helpful in understanding whether the role of the project owner remained central during the information flow: whether Adif was involved in the dissemination of information or the receipt of information relating to variations by the (sub) contractors. The high amount of in-degree information (see Table 3) showed that the financial control function reflected change orders and modifications made by the (sub) contractors, implying Adif's negligible involvement. The level of knowledge dissemination by both Adif and the contractors was less impressive our qualitative data suggested. We noted that the HSL project was largely effective, but with limited scope, contract management, control data gathering networks, and ineffective dissemination networks. This was a major factor in the HSL project being delivered late and over budget (i.e., it overspent on subcontracting).

In summary, the use of traditional procurement, and project owners' lack of reliance on long-term relationships and supply chain management, led to significant incidents, characterized by a high level of reporting (see Table 3, the in-degree information). In turn, the situation was exacerbated by the owner's

limited degree of monitoring capacity. Therefore, the approach to procurement and the management of project implementation had an influence on the project actors' behavior and their potential opportunism. The approach adopted by the owner, when considering the large amount of in-degree data, consequently led to a project owner with low prominence and passive behavior. In other words, the very low profile of owner's communication networks, coupled with the high number of in-degree incidents reported—the modifications—indicated that the project owner lacked effective monitoring of the project.

[INSERT TABLE 3 ABOUT HERE]

We discuss the empirical findings for conditions where the network analysis require much in-depth explication in connection with each reported interaction during the HSL project lifecycle.

A relational approach for project owners to proactively adapt and select contracting parties based on their behavior.

By exploiting the contract database, it was possible to devise a quantitative rule indicating substantial deviations during the first third of the contract period. The rule stipulated that, when one contract had more than three incidents (meaning claims for modifications, requests for cost adjustments, etc.) during the first third of its duration, it qualified as a significant cost overrun (> 17%). Accordingly, the larger the number of incidents (during this period, but also cumulatively), the higher the potential for escalation of costs and time. The confidence in this rule was over 83% (see Table 4). Considering that this rule applied to the HSL project case over time, it implied that the project owner lacked effective control measures and actions; thus, its behavior was passive.

[INSERT TABLE 4 ABOUT HERE]

The figures show, for the same type of contract, a systematic cost escalation bias over time, independent of the contractor involved (see Table 4). As indicated earlier, this was an indicator that no effective measures had been implemented during the contract implementation to deal with them, apart from the already established formal governing rules. Figure 5 illustrates the contractual behavioral patterns, where it becomes clear that no significant reduction in project over-costs is found along the program time when considering different contractors. The above again demonstrates a lack of response capability on behalf of the owner.

[INSERT FIGURE 5 ABOUT HERE]

We then turned to developing the means for improving the project owner's response capacity. This implied adaptation, via small step changes, in the owner's behavior relating to cohesion and flexibility, broadly influencing the long-term development of these complex projects. The Bayesian analysis provided this means (i.e., a comparison between the participants in the project network during the bidding process and their behavior's influence on the contract implementation). By exploiting such elements of knowledge, the factors abstracted from, and identified in, in-network participants' resulting relations can be determined. To this end, cumulative experience from past contracts is crucial for an owner's response capacity. Bayesian inference, within theories of choice, is closely related to subjective probability; often called Bayesian probability (Zhang 2011). Bayesian inference is widely used in a range of disciplines (e.g., in the defense field [Williams et al. 2009, p. 347] and the construction field [Hwang 2016]), and its use in the project management discipline is computationally favorable (Han et al. 2008; Kim 2015). In the following equation (1) we distinguish Bayes' theorem, which can be written as $P(\Theta)$ a prior distribution of a set of parameters Θ; $P(D \mid \Theta)$ is the conditional probability that a particular outcome D would be observed, given Θ; $P(D)$ is the marginal distribution of the outcome D; and $P(\Theta \mid D)$ is the posterior distribution of Θ given D:

$$P(\Theta| D) = P(D |\Theta) * P(\Theta) / P(D) \quad (1)$$

As established previously, the main underlying logic was that the owner's response capacity would be contingent on the behavior of the provider to which the contract had been awarded. The additional element of knowledge was understood in terms of costs/benefits, and the main variations would be due to delays in outcome delivery and cost overruns if we accepted no infringement of the scope. The posterior distribution reflected both the information known a priori (i.e., included in the prior distribution) and the objective information contained in the likelihood function. It centered on a point that represented a compromise between the preliminary information and the data. The project owner's understanding and response capacity could be improved as the sample size increases (Box and Tiao 2011).

The above was a first-order hypothesis; when a second order (i.e., more refined estimation) approach had been established, delving into the incremental evaluation of the outcome when an earned value management system was used became possible (see also Kim 2016). To manage the numerical solution of these problems, a Gibbs sampler with the Markov chain Monte Carlo (MCMC) technique was employed (Smith and Roberts 1993). For a simple approach, the Metropolis algorithm was selected (cf.

Altekar et al. 2004), the application of which enables the checking of the value creation after selecting the bid winner—the provider. The major point to analyze was that different contractors behave in different ways regarding risk and proactivity, as can be seen in Figure 6, which shows posteriori estimated density of probability for cost variations from two different contractors for the same type of contract (civil work contracts).

[INSERT FIGURE 6 ABOUT HERE]

According to Figure 6, and using the RStan tool (Stan Development Team 2018), we derived the potential cost overrun and delay forecasting for the next construction/civil engineering work contract in the HSL project, depending on the selected contractor (see Table 5).

[INSERT TABLE 5 ABOUT HERE]

The means introduced here contrary to subjective judgments of decision-makers provide some objective tools for active owner behavior, which can reduce the transaction costs from unobservability. Yet, as indicated earlier, in the context of public projects, an arm's length relationship with contractors is advisable.

Discussion of Findings

Project front-end stage: Definition and Investment preparation phase (1993-1999)

On December 9, 1987, the Spanish Council of Ministers decided that the new infrastructure should be built using high-speed parameters and with the gauge that predominated in other European countries, i.e., 1,435 mm. Thus, high-speed trains began to be developed in Spain, first the Madrid–Seville HSL (471 km), which went into operation in April 1992, and then the Madrid–Barcelona HSL.

The institutional environment and legal boundaries orchestrating project actor's interaction in the HSL project setting: The rail and transportation industry, has been progressively relying on the contractual relationship. Thus, the institutional environment and the regulatory regime warranted a closer examination of how it influences the HSL project governing processes. Within the HSL project, the importance of the regulatory environment was underlined at every stage. Particularly at the project front-end, and the idea was to engage local (sub) contractors in the project. In Spain, the formal authorization for project investment preparation is given by the Ministry of Infrastructure Development, which instructs the Sub-directorate of Railway Planning to prepare an informative study, i.e., a detailed planning document.

This formal letter of approval of the formal order for GIF (former Adif) was issued at its meeting of May 23, 1997, initiating the start of the construction of the line, including the search for funds to finance the new HSL. However, a detailed planning design had to be completed and approved, so that Adif can start the HSL project (Internal document; Project report, 2002). But Adif lacked authority since the design - the formal order was a strategic input from the sub-directorate of railway planning. To complicate further matters, the formulation of Environmental impact was delayed, and only fleetingly referred to in the project initiation (see also Report, 2003). The PM at Adif reflected the implications: 'There is no time to carry out a feasibility study properly or to evaluate infrastructure needs. There is no time to lose because the elections are in four years.' (Interview with former HSL PM, December 1997). Regarding this situation, the Adif Head of Infrastructure Projects: drew particular attention to the project urgency:

"When the project design was handed to ADIF for further development and delivery, we stepped in: 'the train' was running in full speed and there was no way it could be stopped."

The regulatory environment influenced the tendering process greatly. The HSL project tendering was divided into three parts, closely guided by the management of contracts and the public procurement law [in Spanish: Ley del Contratos del Sector Publico]. As indicated earlier, following the rail industry guides, Adif procured different contract packages within the HSL project comprising tracks and civil work, signal systems, installations, energy systems. These types of work are inherently different, i.e., they required diverse competencies and resources. Consequently, Adif has procured the five types of work by contracting different contractors.

The public procurement law shaped the HSL management governing choices by reinforcing work divisions: procuring design consultants and implementation separately. Following the European tendering statutes and regulations for the sector (Dir.2004/18EC), the lion's share of the contract packages in the HSL project, over 75%, were tendered through prequalification. The procurement occurred at different points in time, considering that the line segmented in three major phases, and the project involved multiple contract packages. Design-Bid-Build (DBB) was mainly used, and Design-Build (DB) was used only for constructing heavy civil infrastructures, such as tunnels and bridges. Within DBB contracts, the contractors were not involved in the design and specification of the work, but the contractors could suggest alternative solutions posterior. That is, Adif discussed the solutions with the contractors. When they were technically

equal and economically complementary to the settlement proposed in tendering documents, then Adif management advanced that solution.

Project urgency: the HSL project –become schedule-driven at the front-end, on catching on the decisions based on the electoral system, in our case study, elections based on four-year orders. Adif Quality Controller draws the attention on proponents and politicians influence:

> "The Politicians, they want the work for tomorrow, and they rush to tell the people that the line will be ready in two years. A politician once told that the line would be open for service in 2003, but as you know, it only did in 2009."

In the same vein, The Quality Controller of ADIF during the interview highlighted:

> "Trying to do things faster, means exactly the opposite. I don't know…, I guess, it is just that due to political pressure, the management initiates the tenders too soon."

In this context, the outcome is a failure of the HSL project. Other actions by the project's proponents included advertising the project as being environmentally friendly, but there were situations in which cost/benefit analysis and their influence were brushed aside. These actions illustrate behavior that has long been recognized in organizational studies (Cohen et al., 1972). Meaning for the project proposal to pass the selection process, it must be overly optimistic, and the cost-benefit analysis not fully considered. A project team member described this behavior during an interview:

> 'It is the higher pressure we have—the schedule—due to political influence: they want to start the project. For them (the politicians and proponents involved), it is important to start the project, but not necessarily to get it done. At least, this is the Spanish way.' (Transcript of the notes collected by one of the researchers during a research-related meeting with GIF management, April 1998)

The contract incompleteness – the latitude for speculation in the contract: The public procurement law advanced the lowest bidder winning. The HSL project was predominantly contractually oriented. In addition, the HSL project contract network had one isolated section—the in-house design team—which was part of the Ministry of Development, constituted a public authority, and therefore could not form a separate contract, see Fig. 3. This isolated actor's activities placed significant pressure on the project owner, leaving a gap in knowledge, and latitude for speculation, in the HSL network. It is noteworthy that the project owner and the design department of the Ministry of Development, at some point during the project, shared the same workspace and resided within a short walking distance of each other, but far from

the construction site. The implications of this for knowledge sharing and the mechanisms adopted were reported by Hetemi et al. (2020). Conclusively, the project owner's role in communication patterns did not correspond with its central contract network position (i.e., Adif's management took a completely hands-off approach). The interviews with the project owner's management showed that the implementation of the project design changes was a source of delay and that many change orders led to cost overruns.

Adif focused on competitive tendering and selected the providers based on the lowest bid/ price. Besides, due to the public tendering law, there were no long-term collaborative arrangements, i.e., procurement was based on a contract-by-contract relationship. Nevertheless, the process is much more complicated because the prequalification tackled on provider's justification of capabilities, which were based on previous work experience, project size, and productivity. Besides, the regulations required that there be multi-prime contracts and that the contracts be a lump sum, fixed price arrangements. That is, competitive tenders for both building works, and specialist packages were invited on an individual, lump-sum basis from the list of pre-qualified contractors (maintained by the project owner). The bids were evaluated primarily on cost grounds. The project owner list sometimes restricted the competence among potential contractors – the pool of qualified contractors was smaller. The cost criterion scores were adopted as indicators, thus, ranking the proposals closer to the average of the total acceptable bidding proposals, which was based on Adif estimations. Given the often-limited number of bidders as well as the regularity of the tendering providers, contractor strategizing was possible. In the case of Adif in general and in the HSL project context, however, there was a requirement stipulating that change orders for all transactions over the specific amount, 10 % need Adif's approval. The 10% legal tolerance created ambiguity and did not make the monitoring of the work impracticable only, but wide open for opportunistic abuse. Hence, we observed that there was neither a political will to examine the likely opportunistic behavior, nor sufficient resources at Adif to exploit these opportunities (Nguyen and Garvin, 2019).

Project implementation stage (2001-2016)

From January 2001 to the entry into operation of the HSL Madrid-Barcelona, 356 main construction work contracts were awarded for €2.03 billion, with a drop of 9.2% on the price Bidding. Adif engaged in contract-per-contract relations with tier-one contractors. The project cost depends on meeting the schedule, while in the words of Merrow (2011, p. 309), being "rushed on the back-end leads to

quality problems" as well. The Project Manager, on behalf of Contractor C, highlighted the following during the interview:

> 'We were awarded the catenary contract, in the first segment Madrid- Lleida in 2006. This was a completely ridiculous situation. It happens to know I can't work because the platform is not done; this, as the installation of the overhead wires are made following other special works, e.g., platform. We lost money, equipment, and other machines were blocked in the field. Due to our long cooperation, we did not consider legal actions!'

Once the permission to start the implementation work was received, construction works were initiated. Yet, the start of the works was delayed in 30% of the contracts, the average delay being 7 months from the signing of the contract (Report, 2017). Although in many cases, as in the executed contract of works on the platform construction project for the Madrid-Zaragoza-Barcelona high-speed line, section: "Martorell-Río Llobregat," the delay was 30 months. These delays were fundamentally due to the fact that the bidding for the works contracts began without having begun the procedures of forced expropriation of the affected lands, giving rise to the suspension of the start of the works (Report, 2013).

Below is a detailed explanation of the event of incidents in some cases, which factor 65% of the cost of the sample analyzed, and which are considered especially relevant. For instance, within the section: "Tramo Hospitalet – La Torrasa" (Internal document, 31/04). Throughout the life of this contract, eleven extensions were authorized for the execution of the works, which meant a total increase of 38.5 months, 192.5%, compared to the initially agreed term. In the reasons for these extensions, reference was made to the incidents that occurred during the execution. In June 2006, the contractor presented a first proposal to modify the contract, which was justified by technical issues, and that implied significant modifications with respect to the awarded project with high technical and economic repercussions, raising the contract price by €20.47 million (19%) and the execution period in 4 months. Adif management authorized the drafting of the modified project. However, this project was not approved due to a series of events that are described in the following paragraphs of this and culminated in the presentation in April 2008 of a second proposal for the modification of the original project for the amount of €17.19 million and an execution period of 4 months, whose file was approved on April 20, 2009.

Similarly, within section: "Olredola-Avinioynet del Penedes." The contract was awarded on July 5, 2002 with a drop of 21.4%, for a price of €37.46 million and a term of execution of 22 months, with a

reduction of 9% of the expected term. The incidents that arose during the execution of the contract (four extensions, a modification that also extended the term by another 4.5 months, three price revisions and two additional settlements plus a complementary works contract) raised the cost of the works initially foreseen in the main contract by 68.4%, and the execution period at 138.6% more than the initial term.

Numerous modifications have been detected in multiple contracts, and section projects that did not meet the requirements of article 101 of the public procurement law (Report, 2013, 2017). The above are few illustrations from main contracts. Article 101 mandates, in order to exercise the justification prerogative, the existence of new needs or unforeseen causes that must be duly justified in the file that motivates the modification. But, on some occasions, questions that responded to defects in the projects due to indefiniteness or omissions were classified as new needs or unforeseen causes. On other occasions, the modifications of the contracts were motivated by a faulty execution in construction, (by way of an example is expressly stated in the one of the internal reports justifying the extension of the service contract of the infrastructure of the HSL project).

Being under the regulatory regime, Adif relied on formal governing mechanisms involving site control that required expertise in constant monitoring. Yet, Adif was often understaffed, one of the project team members highlighted this during the interview:

> 'I lack support and human resources to carry out my work with colleagues. We have only three engineers, and it is difficult to cover the whole project—it's actually ridiculous! It's impossible to cover the work. I had to cope with five contracts at once, and we needed, like, five or six people to take care of the workload in the field.' (Interview with the Quality controller at ADIF, April 2017)

The passive project owner: Adif did little in building relationships with the providers. It was worse with respects to learning from provider's behavior patterns – the learning processes where not adequately put in place. The initial database they set in place contained a lot of information but was ineffective. The accountant manager who maintained and updated this database/folder at Adif reflected of its impractical state:

> "The idea is to capture the changes in the scope of work, and track and address them properly in the next line segment. [But] after multiple entries it became messy and it is difficult to update it accordingly as it is not system-based. It relies on manual updates and has no automatic coverage

reflecting the actual certificate of changes when they occur on site." (Transcript of a research-related meeting with Adif management, November 2017.)

Moreover, Adif lacked integration and a smooth flow of communication. In the words of Merrow (2011, p. 162), "when companies do not cooperate internally, they become incoherent and they become easy prey for opportunistic outsiders." We found relationships between the contract type and the contractor's/provider's behavior. To this end, different contract types and diverse providers affect the contract differently through more contract changes or variation orders, including several unforced owner-proposed project changes (see project owners in degree, Table 3).

Multiple 'delusions': The project urgency together with the contract ambiguity set the scene for change orders, which included project choices in the form of negotiated agreements. These choices sometimes undermined project efficiency. Some project members blamed the contractors:

'There are also changes when the design is not done properly. When this happens, contractors and suppliers try to make money. In that respect, they are opportunistic if they have the chance. So, when you have a problem, and you change the approach from the one agreed, you have to 'negotiate' the changes and, foremost, agree on the pricing. When we are over schedule, we usually end up agreeing.' (Interview with the construction manager, October 2016)

In such conditions, the governing process was dominated by negotiations and compromises. Besides, some contractors often influenced the decisions by detecting problems and deciding solutions for the project. During the interview, the contractor expressed the following:

'I've seen cases where construction companies go and speak with the local administration with responsibility for that region and ask for expected changes based on the regulatory territory; so, when changes occur, it is because of the construction organization's manoeuvres.' (Interview with the Engineer at Organization C, June 2017)

The findings above outlined through the project lifecycle corroborated our theoretical analysis and propositions in sequence as well as extended our detailed case analysis with an in-depth case background.

Conclusions

Large-scale infrastructure projects, as temporally-limited and goal-oriented contexts, are characterized by two focal stages: 1) the project front-end and 2) project implementation, offering a unique setting for the study of inter-organizational relations and actors' behavioral patterns. Each lifecycle stage is delineated by distinctive constituents that affect both the governing activities and the project actors' behavior and strategizing (Havenvid *et al.*, 2019). However, although the existing literature has recently sought knowledge of inter-organizational relations and governance issues in large-scale infrastructure projects, the researchers developed static, non-time-related propositional statements instead of dynamic, time-dependent ones. The static propositions failed to explain thee development of project actors' behavioral patterns during the project lifecycle. In addition, the existing literature, for the most part, has provided a first-order view of dyadic project owner–contractor relationships, seeking to explain the effects of interpersonal relations and behavioral attributes for the potential governing activities and actors' behavior. By employing a project lifecycle perspective, and examining the actor's interdependencies from a network analysis perspective, this paper contributes a viewpoint that has largely been missing from the existing literature (cf. Söderlund 2011).

The case revealed strong concerns from responsible people at the front-end stages of projects. According to our informants, the priority at the front-end stage was to give impressions of progress. By promoting the efficient and quick public bidding process, to perform in front of the citizens. We observed it was strongly linked to the electoral cycles, introducing urgency in the project. To this end, Fig. 5 shows a piece of clear evidence for general election calls. Besides, semi-structured interviews confirm such behavior notably. Whereas the existing literature has stressed the importance of contract design in mitigating cost and time overruns (Winch 2010; Gao et al. 2018), this study found that an intricate contract design only partially explained the dynamics that drove escalation and other issues identified in the case analysis. Through empirical analysis, we positively confirm the proposition 1 that the project urgency induced by influential project promoters at the project front-end amplifies the project uncertainty and incapacitates well-prepared decision and implementation. The overpressure in the front-end reduces the quality of designed solutions and, in the end, influences the cost overrun to the final term for these contracts.

The findings explained above for the effects in proposition 1, have their logic continuation in proposition 2 – that the initially created urgency increases the likelihood of more ambiguous contracts. So, the created uncertainty has its actual impact during the implementation stage of the project lifecycle. It becomes clear from the case study, where the cost increase is not a constant. It grows densely during implementation stage due to modifications and faulty incidents which did not follow the requirements of article 101 of the public procurement law. In all the analyzed contracts in which modifications were made, the provisional continuation of the works was authorized. This action was justified because the stoppage of the works during the processing of the modified ones supposed a serious damage for the fulfilment of the execution terms that, nevertheless, were exceeded widely (Report, 2017). In addition, the causes for the delay and the reasons for which it is considered that they are not attributable to the contractor were not clearly detailed in the files for processing extensions of contracts.

Figure 5 shows how different contractors have different expectations regarding the past pieces of evidence, as one of them manages to end up most of the contracts with over costs around 18% on average. In addition, the case analysis uncovered an interesting inconsistency concerning the optimal timing for coping with uncertainty in a large-scale project setting. While confirming the proposition 2 positively, we extend the dominant perspective in the engineering and project management literature which often confines uncertainty management to the early stages of projects, i.e., to the project front-end(e.g., Oh *et al.*, 2016; Samset and Volden, 2016). Such uncertainty management is non-effective (at least partially effective we found). In practice, we observed that due to the meta-rules and some opportunistic contractors' behavior, the project owner would not be able to take effective action at the front-end.

An active owner role remains vital as a project progresses through the detailed design phase and into the implementation phase. When we consider the implementation stage-related propositions, it appears as evident that the uncertainty influence is on the causes of escalation dynamics. The outcome of these recursive escalation dynamics explains the time and cost overrun of the Madrid–Barcelona HSL project. Therefore, it becomes critical that the owner profile becomes active – leveraging the response capability, trying to reduce such escalation, which is precisely the point for Proposition 3 describing the negative consequences of project owner passivity. To this end, the case study has shown how the SNA tool can bring pieces of evidence for different providers exhibiting different dyadic relationship with the infrastructure owner when delivery and information flow is considered. Such an approach suggests that

general governance rules need to be tailored accordingly. In this context, the effectiveness of project owners' management of uncertainty vis-à-vis the functionalities to be delivered, and their providers' behavior must be addressed proactively and on time. The above suggests that more attention needs to be given to the project actors' roles, their interdependencies, and the institutional context.

The presented case also enables us to see what can be evidenced as the deliberate misinterpretation of outcomes ending up with a different level of cost overrun. Those practices are attested from the data for many different contractors and types of contracts and presented just for two of them, see Fig 6. Those we also positively confirmed Proposition 4. The lessons learned from this case enabled us to develop strategies that project owners need to take on board to increase their response capability and become active (coping with what it was discussed at the level of proposition 3). Hence, after the bidding process, the winning contractor behavior should be closely monitored to help develop a specific risk management plan for execution vis-a-vis contractor's behavior and implementing specific mitigation actions looking to cope with its 'well-known actions/claims.' See table 5, where such knowledge shows the different expectations found depending on contractors' behavior. Hence, the case study was not only used as a confirmation for the proposition meaning, but it was made possible to derive specific tools providing additional added value knowledge for the owner, i.e., tools enabling the more active owner behavior. We discuss practical implications in the following section.

Practical Implications

To conceptualize the two available transaction sets, 1) the contract and 2) information exchange (flow), in the HSL project, a thorough network analysis was performed. The density and project owner centrality relating, in particular, to the latter set, was seen as a critical SNA measure for analyzing inter-organizational relations (cf. Pryke 2012). Considering that the different functional classes of these two network sets yield a measure of the maturity of a specific actor (see Pryke 2012; Verschoore and Adami 2020), it is proposed that changes in the actors' centrality might provide an essential measure of the structural and relational dynamics in project networks. Comparison of the centrality values in the contractual and information exchange networks, for a given actor, indicated a measure of the actor’s role within the procurement approach, revealing the influence of the procurement approach on actors’ behavior.

This study found that, in a large-scale project context, uncertainty accumulated in layers; it had roots in the public project institutional context (the procurement approach), contractual incompleteness or ambiguity, and the lack of relational governing mechanisms, among others. Therefore, monitoring the uncertainty relating to contractors' behavior is a reflective practice essential for project owners (Liu *et al.*, 2014). It is worth noting that one transaction does not provide an opportunity to learn about other parties' behavior. Still, repetitive operations allow for learning about the behavior of the other parties and the generation of trust. This is favorable in a large-scale project setting when considering that contractors are repetitive (i.e., each runs multiple contracts during the project lifecycle). We suggest that the focus should be on the large contractors and consortiums as they can impact project outcomes, see Fig. 2. Such an approach requires a broader perspective and understanding of the relevant data, and adequately staffed owners' teams are crucial.

Finally, a move was made to provide some means of first-tier analysis, as presented. By exploiting certain knowledge, the factors abstracted from and identified in, in-network participants' resulting relations could be retrieved. To this end, the Bayesian analysis was proposed to examine the participants in the project network during the bidding process and their behavior's influence on the contract implementation. The means proposed here can help project owners interpret the organization's explicit knowledge and encourage its utilization by measuring the regular incidents that contractors have exhibited on previous projects, using these measures to make the current project scoping more robust. Such internalization of knowledge, based on contractors' behavior, can stimulate learning processes across (sub) projects in large-scale infrastructure projects. The statistics indicated that providers' potential behavior demanded particular governing choices regarding contractor selection and monitoring (cf. Le et al. 2020). Thus, depending on the figures (see Table 5), the project owner's response capacity needs to be closely linked to the risk analysis of the contract implementation. The managerial implication of this new knowledge acquisition is crucial in bringing the uncertainties of the project setting from the unknown domain into the realm of risk, enabling the incorporation of such knowledge in a project risk management subsystem. After that, specific mitigation strategies or contingency actions can be planned or adopted, yet their discussion falls beyond the scope of this paper.

Limitations and Future Research Directions

Although this research advances the understanding of formal and relational governance in large-scale infrastructure projects by exploring actors' behavioral patterns sequentially, and in view of the project public institutional context, some limitations should be recognized. First, we accept that our single case study on the Madrid–Barcelona HSL project has enabled only an analytical generalization of the findings (Eisenhardt and Graebner 2007). Despite providing an in-depth understanding, we encourage other scholars to examine the structural and relational aspects of governance using multiple-case studies.

Further research should continue to enhance the understanding of this relationship from other perspectives (see, for example, Liu et al. 2019). The elaboration, based on two contingent dimensions, namely project urgency and contract ambiguity (concerning Propositions 1 and 2), should not be understood as the analysis of a "typical large-scale project"; however, we confirm that the contingent dimensions indeed provide insights for a deeper understanding of projects beyond the traditional engineering approach. This line of work can be further extended to involve other contingent variables relating to contracts or the size of projects. Considering that project size influences governing practices, requiring different strategies and approaches for coping with uncertainty (see Gil and Pinto 2018), it would be interesting to investigate it across different project and organizational sizes (e.g., adopting Flyvbjerg's [2013] typology). Besides, it can be observed from our case analysis that due to the traditional DBB system, separate entities in the government lead with different portions (design, legal, contracting, etc.). As illustrated by our case, this separate design and construction of the project owner placed significant pressure on the governing process, leaving a gap in knowledge, and latitude for speculation, in the HSL network. Hence, we suggest project owners to introduce strong controlling of the engineering design, and dedicate to facilitating the communication among these separate entities. We also suggest this line of work to advance further by investigating and proposing collaboration techniques among government entities.

Despite these limitations, we believe that large-scale infrastructure project contexts offer an excellent opportunity to examine the dynamics of relational parties' and actors' behavioral patterns. The propositions developed here need to be further empirically tested; thus, the individual propositions can be employed to build hypotheses and test them through quantitative research (e.g., questionnaire surveys). Testing the propositions in different empirical contexts would offer researchers a comparison across settings. It might be that the impact of specific elements captured here (e.g., project urgency, multiple

delusions, and escalation dynamics) may differ. In particular, the identification of more nuanced aspects is needed, which are more likely to be considered by managers for large-scale project governance; for example, the active project owner and its response capacity proposed here may be further advanced to understand the implications of management choices in large-scale project settings across contexts (e.g., countries and industries). This would enable researchers to empirically investigate and enhance the generalizability of the findings to other fields. Conclusively, a lifecycle perspective could be further advanced and studied in different types of project contexts.

Data Availability Statement

Some or all data, models, or code generated or used during the study are available from the corresponding author by request (the database generated during the current study for the purpose of quantitative analysis is not publicly available but the data sets are in our repository and we could provide to the editor and the reviewers of the paper on reasonable request).

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Tables

Table 1. Summary of data collection

Data collection method		Data collected
Semi-structured interviews	First interval (1996-2010)	40 interviews with the HSL PM, Adif Quality Controller, Head of Infrastructure Projects, Engineer at Organization B, project proponent and other relevant actors. Average duration was slightly over one hour.
	second interval (2015-2018)	12 interviews with the program managers and other relevant actors (project managers, construction manager at Adif, Organization 'A' Contractor PM, Organization B Supplier, Organization C Contractor PM). Average duration was slightly over one hour.
(Participant) Observations	First interval (1996-2010)	➢ participant observations, ➢ group interviews, ➢ Extensive informal communication
	second interval (2015-2018)	The insider spent 2–3 days per week at the organization's offices and conducted observations: ➢ 7 management meetings; ➢ Extensive informal communication; ➢ Field notes for each of the days spent on site;
Document analysis	In total more than 20 documents: ➢ Internal program documents (internal financial and audit reports, overview presentations, internal organization and escalation matrices, lessons learned, and program tools, e.g., risk logs). ➢ Organization-wide guidelines and frameworks for project and program risk management. ➢ 90 pages of public material drawn from the press coverage of the project.	

Table 2. Contracts and incidents in the implementation of the HSL Madrid-Barcelona

	No.	**Imports***
Main Contracts	666	5.406.322
Modifications	141	622.824
Contracts for complementary works	34	161.128
Contracts for emergency works	9	239.867
Price revisions contracts	355	477.579
Liquidation and additional others	481	418.405
Total	1.686	7.326.125

* figures in thousands of Euros

Table 3. Properties of the HSL project relational structure

Measurement	**Contractual**	**Information**
Number of actors	23	23
Density of the network	0.555	0.327
Centralization	0.828	0.849
Average path length	1.889	1.285
Centrality of project	0.968	0.378
In-degree of project	15	15
Out-degree of project	28	2
Transitivity	0.072	0.075
No. of isolates	1	4

Table 4. Analysis of contractor behavioral patterns: number of incidents and escalation in cost

Data Query: > idf [idf$num<3 & idf$duration > 10,]			Incidents			Total
Contract Id	**Origin (year)**	**Duration (months)**	**Num.**	**Ini.**	**Fin.**	**Cost overrun (%)**
2914	2009	12.0	2	1	1	4.23
3313	2009	11.5	2	0	1	0.00
393	2010	11.0	1	0	0	0.82
3683	2010	13.0	0	Inf	- Inf	0.00
3822	2011	12.0	0	Inf	- inf	0.00
5087	2014	12.0	1	1	1	0.00
Data Query: > idf [idf$num>9 & idf$duration > 10,]						
1861	1998	20.0	11	0	4	10.60
1086	2001	17.5	12	0	7	27.66
2294	2003	21.0	13	1	6	38.56
4782	2005	26.0	15	1	10	39.41
2908	2007	26.0	16	0	9	28.95
4361	2008	19.0	15	1	7	11.52
5158	2010	22.0	13	0	6	25.48

Note: **Num. –** total number of incidents throughout the contract**; Ini. –** timespan (years) for the first incident since the starting of the contract; **Fin.** – timespan (years) for the last incident since the starting of the contract

Table 5. Expected cost and delay for the next CONS construction work contract to be awarded

Contractor	**Foreseen cost-overrun (%)**	**Foreseen Delay (%)**
A	3.9	0
B	-1.5	12.1
C	2.5	16.6
D	0.4	43.8
E	7	9,3
F	0.7	1
G	5	27.6