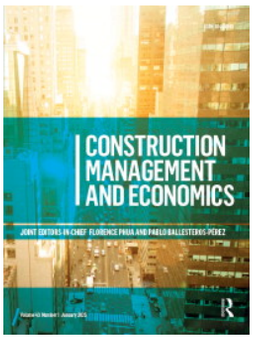

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Challenges with collaboration: the interaction of formal and informal ties in infrastructure construction

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ABSTRACT

Collaborative project delivery models (CPDM) have been introduced in infrastructure construction delivery to improve project outcomes and reduce adversity characteristic for the field. Recent research discusses the interaction of formal and informal governance but highlights the need for further research into the interaction as well as its functions and dysfunctions. With help of a social network lens, we study how collaboration in a CPDM can be understood by the interaction of formal and formal ties and their (dys)functions. Based on 45 in-depth interviews, observations and document analysis, we studied two major infrastructure construction projects utilising a CPDM and the challenges caused by the interaction of formal and informal ties. Our results indicate that these two types of ties interact in a cyclic fashion, where formal ties form the foundation to develop informal ties, and informal ties shape how formal ties are understood. Strong formal and informal ties have both positive as well as negative consequences for collaboration in a CPDM. Furthermore, although these challenges can be beneficial to certain parties in the project, they can also be dysfunctional to other parties. The research contributes to the academic debate on the interplay between formal and formal ties.

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Infrastructure construction; project delivery; project network; formal ties; informal ties; tie interaction

Introduction

Collaborative project delivery models (CPDM) have gained increasing popularity for organising infrastructure construction projects in the last decade as a solution to the challenges posed by the inherent complexity (Geraldi *et al*. 2011, Hietajärvi *et al*. 2017), risk multiple stakeholders (Lehtinen and Aaltonen 2020) and highly political context (Matinheikki *et al*. 2019) of infrastructure construction. These factors, combined with traditional fears of adversity, low productivity and conflict (Hansen-Addy and Nunoo 2014), have led to the adoption of these new project management models, many of which focus strongly on collaboration (Chen *et al*. 2018, Kadefors *et al*. 2023) and rely on relational contracting principles in which both formal contracts as well as informal mechanisms are viewed as governance (Bygballe *et al*. 2015). These models have become especially popular in interorganizational projects (IOP), such as infrastructure construction.

Literature on inter-organizational relationships (IOR) shows that formal contracts and relational governance play a key role (Cao and Lumineau 2015, Roehrich *et al*. 2020). In this literature contractual governance focuses on the importance of contracts and formal rules, while relational governance in IOR is governed by social relations, trust and shared norms (Cao and Lumineau 2015), which are perceived as reducing opportunism (Poppo and Zenger 2002). Both governance forms are seen to complement each other (Poppo and Zenger 2002, Kadefors 2004, Wang *et al*. 2021) and have a joint impact on performance (Cao and Lumineau 2015, Wang *et al*. 2021). From reviews on contractual and relational governance as well as formal and informal approaches, contractual governance has often been discussed from transaction cost theory or agency theory while relational governance has been studied with social capital, social exchange and capability frameworks (Cao and Lumineau 2015, Roehrich *et al*. 2020, Winch et al 2023). For example, Winch et al (2023) argue that traditional views offer valuable insights into the mechanics and formal frameworks of projects but lack the power to explain social

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interactions and informal networks. Furthermore, knowledge gaps indicated in IOR governance research relate to the impact of prior relations, the lengths of relationships on governance, and the interplay between relational and contractual governance and possible dysfunctions (Howard *et al*. 2019, Roehrich *et al*. 2020). Much of the work on IORs has however been focusing on dyadic relations or in permanent firms, but less focus has been on IOP in which multiple organizations collaborate.

Previous studies on more collaborative contractual models in construction have discussed the importance of focusing on the relationships between actors and processes of collaboration next to the formal contract and the interplay between formal and informal aspects which influence each other (Bresnen and Marshall 2000, Bygballe *et al*. 2015, Bygballe and Swärd 2019, Nilsson Vestola and Eriksson 2023). Further, earlier research has shown that governance strategies depend on relational ties embedded in a firm's economic setting (Granovetter 1985, Yang *et al*. 2011), and thus focusing on relational ties can give insight in IOR. This can also be found in the construction literature in which a rise of relational governance coincides with an increase in network studies in construction (Zheng *et al*. 2016, Pryke *et al*. 2017), a perspective especially well-suited to understand the complex inter-organisational context of infrastructure projects (Pryke 2012). Particularly social networks have garnered much attention (Pryke 2012, Zheng *et al*. 2016) in the construction literature as they help unearth the informal dynamics in the project (Pryke 2012, Papadonikolaki *et al*. 2017), important for relational governance. However, this view excludes the interaction of relational dynamics with the formal project framework, such as the contract or project organisation. Recent research with a focus on networks has therefore combined the formal and the informal, for example in discussing BIM-implementation (Papadonikolaki *et al*. 2017), knowledge governance (Biersteker and Marrewijk 2023) and the importance of the fit between the formal and informal institutions in construction projects (Wang *et al*. 2018).

However, while relational governance, collaboration and early actor involvement have been introduced as the solution to the challenges in the construction industry, Kadefors *et al*. (2023) point to several challenges of implementing relational governance in the construction industry requiring further attention. This viewpoint is reflected in the challenge of combining relational and contractual governance (Roehrich *et al*. 2023). Moreover, procurement literature mainly focuses on formal aspects of the project, such as contract or project model, while social network researchers often focus on analysing tie strength and the opportunities they provide network actors. The growing body of literature on the interaction of different types of ties (Papadonikolaki *et al*. 2017, Wang *et al*. 2018, Biersteker and Marrewijk 2023), viewing the project as a combination of formal and informal ties (Adami and Verschoore 2018), point to the importance of understanding this interaction, an aspect especially pertinent in projects utilising CPDM.

The recent focus on relational governance moves metrics of project success away from purely economical and contractual aspects and emphasises social interaction and informal relations. While several studies have mentioned the importance of the interplay between formal and informal aspects of collaborative delivery models (see Bygballe *et al*. 2015, Nilsson Vestola and Eriksson 2023), the focus on qualitative social network approaches has been limited. There is thus a need to understand how the formal framework –as defined during procurement– shapes the project's social network in the delivery of infrastructure projects. Moreover, when combining the long-term, ambiguous infrastructure context with the recent focus on relational governance and collaborative project delivery models, Roehrich *et al*. (2023) found that neither the interplay between formal and informal ties nor the reasons how collaborative dynamics appear as a result of this interaction are sufficiently explored.

This need is visible also in recent calls for attention and further insight into the configuration of ties as well as the tie characteristics themselves (Granovetter 1973, Papadonikolaki *et al*. 2017, Biersteker and Marrewijk 2023). This is moreover related to the reported knowledge gap in the interrelation between contractual and relational governance and their function and disfunctions (Howard *et al*. 2019, Roehrich *et al*. 2020).

The aim of this paper is to provide empirical insights on the interplay between formal and informal ties in two infrastructure delivery projects based on a collaborative project delivery model. We specifically focus on the following research question: *How can collaboration in a CPDM be understood through the interrelation of formal and informal ties and their (dys)functions*?

This research adds to the growing body of network literature in construction and relational governance, with a focus on the formal and informal ties between project actors. In particular, we contribute to the ongoing debate on formal versus informal governance in IOP and relations in which the focus is on the

interplay between formal and informal ties and possible functions and dysfunctions this interaction could provide. First, our results indicate that formal and informal ties interact in a cyclic fashion, where formal ties form the foundation to develop informal ties, and informal ties shape how formal ties are viewed and understood.

Second, our results propose that a strong tie (formal or informal) can be a barrier for collaboration and other tie development in CPDM projects. Third, we discuss that these challenges or dysfunctions of strong and weak formal and informal ties develop over time and a strong formal/informal tie can be beneficial to certain parties but dysfunctional to other parties.

Collaborative project delivery – formal and informal governance

The uncertainty, complexity, involvement of multiple stakeholders, coupled with a high level of political sensitivity make large infrastructure projects challenging to manage and deliver to specifications (Matinheikki *et al*. 2019, Brunet 2021, Denicol *et al*. 2021). Larger infrastructure projects are moreover often long-term, spanning years and even decades. Since few clients have the requisite abilities and resources to deliver such undertakings (Eriksson 2015, Denicol *et al*. 2021), infrastructure projects by nature become interorganisational endeavours (Jones and Lichtenstein 2008, Eriksson 2015). The tensions of aligning several separate organisational goals and practices with the overarching project goal characterise these projects (Jones and Lichtenstein 2008), as well as the client's lack of requisite abilities (Denicol *et al*. 2021). Relational or informal governance and collaboration have become increasingly popular, both as tendering requirements and as terms in construction management literature as a way of aligning disparate goals and ensure successful project delivery.

In this paper, we define collaboration as the evolving practice created between separate, autonomous stakeholders who engage in an interactive process, guided by shared rules, norms and practices to achieve a common goal (Wood and Gray 1991, Castañer and Oliveira 2020, Gomes and Tzortzopoulos 2020), and informal governance as governance by shared values, norms and collectively understood processes (Poppo and Zenger 2002). Informal governance thus relies partially on collaboration.

The introduction of informal governance into the infrastructure industry, based on experiences from the North Sea oil rigs (Lahdenperä 2012, Walker and Lloyd-Walker 2015) and to combat adversity and the perceived underperformance in the construction industry as first discussed in the Egan and Latham reports in the 1990s (Pryke 2005, Ryd 2014, Nwajei *et al*. 2022), has led to a plethora of different project delivery models. Their recent adaption in the Nordics have been met with varying degrees of success (Kadefors *et al*. 2023). In this paper, we use the umbrella term *collaborative project delivery models* (CPDM) to refer to these different solutions (Walker and Lloyd-Walker 2015, Bygballe and Swärd 2019, Nwajei *et al*. 2022). Although they differ in terms of contract and organisational set-up, they all incorporate early inclusion of key parties, sharing of resources and joint decision-making as well as a high reliance on relational governance (Lahdenperä 2012).

Although the discussion on the balance between formal contracts and informal relationships as governance mechanisms has been ongoing for over two decades (Poppo and Zenger 2002, Bosch-Sijtsema and Postma 2009, Chen *et al*. 2018), and a recent review requests for more case studies and qualitative studies in the interorganisational relationship field (Roehrich *et al*. 2020), little attention has been paid to the implementation phase. Literature on relational and contractual governance also discusses positive and negative implications of the interplay of the formal and informal framework. Positive formal aspects are related to safeguarding interests, clarifying responsibilities and roles and coordination as well as learning (cf. Klein-Woolthuis *et al*. 2005, Howard *et al*. 2019). Positive informal aspects are mentioned by Howard *et al*. (2019) as sharing of information and communication, reduction of uncertainly and decrease of formal control costs. More negative aspects of formal contracts can be coordination failure or derailed exploitation and conflicts (Howard *et al*. 2019). Negative aspects of relational and informal aspects can be cognitive lock-in and relational inertia (Gulati 1995) and suboptimal information search and poor decision making (Uzzi 1997). However, according to Roehrich *et al*. (2020) there is limited research on this. Furthermore, these consequences are not always related to social networks and ties.

In construction literature, the introduction of collaborative project delivery models in the infrastructure sector has not gone unnoticed (Lahdenperä 2012, Nwajei 2021) and recent studies within relational governance have for example investigated the alignment of project practices and stakeholder logics (Matinheikki *et al*. 2019), the mechanics of identity formation (Hietajärvi and Aaltonen 2018) and the interaction of contract and

relationships (Wang *et al*. 2021). Other studies related to CPDMs discuss the interplay between informal and formal aspects, practices, or governance and how they either complement each other or influence each other in cyclic processes (Bygballe *et al*. 2015, Nilsson Vestola and Eriksson 2023).

A social network lens on CPDM

Interorganisational, long-term infrastructure projects have to rely more on self-organising than traditional project management methods, such as the iron triangle or planning and risk analysis (Wøien *et al*. 2016, Pryke *et al*. 2018). As CPDM mainly rely on social interaction and governance by commonly agreed practices and norms (Lahdenperä 2012, Walker and Lloyd-Walker 2015, Nwajei 2021) in complex, large-scale contexts (Pryke *et al*. 2017), viewing infrastructure projects through a social network lens becomes a relevant approach. In this paper, we primarily focus on IOP (see Sydow and Braun 2018), which interacts on multiple levels: a level above the project such as industry customs and drivers from the home organization, and a level below the project, such as the individuals from these organizations. According to Sydow and Braun (2018) these projects can be embedded in a project network developed on longer term interpersonal or inter-organizational relations (Lundin *et al*. 2015).

A social network can be defined by actors "linked to one another by social *ties*" (Wasserman and Faust 1994, p. 18). Actors in this respect can be either individuals, organisations or larger social entities (Wasserman and Faust 1994). According to Wasserman and Faust (1994), the inclusion of information pertaining to relationships (or social ties) makes the social network view fundamentally different from other network approaches. Although network studies have hitherto mainly focused on actors and their characteristics, as well as how their relationships can constrict or empower them in the form of social capital (Solheim-Kile and Wald 2019) or structural holes (Burt 2001), a growing subset focuses on tie characteristics specifically (Wang 2016, Papadonikolaki *et al*. 2017, Zeng *et al*. 2022).

However, merely looking at the social ties restricts our understanding of the complexities of an infrastructure project and its development. We must therefore include other aspects of the project organisation and thus look at the project as a whole, comprising both social as well as formal ties, in the form of for example contract and project organisation.

Tie types in projects

Recent research shows that the quality of the relational ties are not based purely on the formal framework, but also on interaction within the project (Wang *et al*. 2021), and how the fit between formal and informal institutions can improve project outcomes (Wang *et al*. 2018). The introduction of CPDM is therefore not enough to ensure project success in the infrastructure industry, as this action only focuses on the formal framework, but requires a deeper understanding of the interaction within the project.

A project network in an IOP is created among the participating actors, both organisations and individuals (Hellgren and Stjernberg 1995, Adami and Verschoore 2018) by the interaction of formal and informal ties (Papadonikolaki *et al*. 2017, Biersteker and Marrewijk 2023). *Formal ties* are the officially recognised ties between actors, such as the project contract and project organisation, as well as project meetings and documentation (Papadonikolaki *et al*. 2017), such as designs and plans prepared for the delivery stage (Shen and Chang 2011). Other formal aspects include allocation of authority, reward and incentive systems and the project structure (Biersteker and Marrewijk 2023). *Informal ties* comprise of the developing relationships within the project and unplanned social interactions (Papadonikolaki *et al*. 2017, Biersteker and Marrewijk 2023), such as site visits (Shen and Chang 2011). Project culture and trust can also be included under this heading (Biersteker and Marrewijk 2023).

Strength of ties in IOP

Social ties exists on all levels in the project hierarchy, both between individuals and organisations (Granovetter 1985, Uzzi 1997). In the construction industry, this can be seen in the long-term relationships within supply chains (Eccles 1981). These ties can facilitate resource flows and information dispersal, depending on their strength and structure (Granovetter 1973, Uzzi 1997, Battilana and Casciaro 2012).

Strong ties are defined by the amount of interaction, the length of the relationship and the emotional intimacy of said tie (Granovetter 1973, Zeng *et al*. 2022). Strong ties encourage trust and sharing between the connected actors, as well as improve communication (Papadonikolaki *et al*. 2017) and aid in the formation of a shared project culture (Hietajärvi and Aaltonen 2018). *Weak ties* are lower on the aforementioned dimensions and can create cliques in the network, separating actors (Battilana and Casciaro 2012). Weak ties can also be conceptualised as the

common understanding of the project: when actors do not view a tie in the same way, be it formal or informal, it is weak.

Actors in projects with strong social ties are comfortable in bringing differing opinions to the table (Kadefors 2004, Battilana and Casciaro 2012, Papadonikolaki *et al*. 2017), which can result in constructive task-related conflict (Zeng *et al*. 2022) as actors' viewpoints on how to best execute a task differ and the quality of the resulting decision improves (Jehn and Mannix 2001). According to Zheng et al. (2016), a common understanding of the project's goals ensures an aligned understanding of the project, and keeps the task-related conflicts to technical details rather than evolving into fundamental conflicts about the project's purpose (Zeng *et al*. 2022). This echoes earlier findings from the conflict literature, where for example Jehn and Mannix (2001) discuss different types of conflict in group settings. CPDM relies on relational governance to achieve strong, high-performing teams with low relational conflict and improve project outcomes by introducing contractor expertise in the early project phases (Lahdenperä 2012). The information sharing enabled by the strong ties moreover reduces relational conflicts (Zeng *et al*. 2022). However, homophily is a recognised challenge of this set-up, since the lack of diverse values, reducing relational conflict, may lead to uniform decisions, leading to less optimal outcomes (Jehn and Mannix 2001, McPherson *et al*. 2001). There is thus a challenge in balancing strong and weak ties with the desired benefits of CPDM, even though authors point to the importance of fit between the formal and informal spheres (Wang *et al*. 2018, Biersteker and Marrewijk 2023).

The project relations are thus created by task interaction and personal interaction, or, in other words, interaction between the formal and informal framework and their strong and weak ties. As project governance shift towards relationships and interpersonal collaboration rather than the traditional contract-based coordination, the project dynamics change (Yang *et al*. 2011).

Method

With the aim of generating contextualized explanations (Welch *et al*. 2011) and gaining a deeper insight on the impact of CPDM in infrastructure construction projects, a qualitative research approach was chosen. A case study approach was deemed relevant to provide a critical and illustrative example as rich, qualitative data can explain the complex social processes within an IOP organization (Eisenhardt and Graebner 2007, Siggelkow 2007, Ketokivi and Choi 2014). We use two case studies as illustrative examples. The cases take place in different contextual situations (different countries) and have different contractual set-ups but illustrate complex and large infrastructure projects using a CPDM approach.

For this type of case-based research as theory elaboration, we applied abductive resoning (Ketokivi and Choi 2014), in which we initially started inductively with collecting data and related the data to different types of ties in the analysis, while turning to theory during the process to refine our approach. Thus, we continuously matched theory and reality between our conceptual background, empirical material and analysis.

Research context

We focused on two major construction infrastructure projects in a Nordic context (see Table 1). The two cases classify as major projects in terms of their cost being between one hundred million and one billion

Table 1. Case descriptions and data collection.

	Case Train	Case Tram
Length	9,5 years (estimated)	6,5 years (estimated)
Monetary value	475 million €	390 million €
Contract type	Bilateral (client-contractor)	Multi-party (main participating organisations)
Governance characteristics	Co-located project office; common document platform; collaboration charter; open books; closed management meetings; contractual conflict	Co-located project office; common document platform; unanimous decision-making; open management meetings; open books; transparency
Interviews	20 interviews	25 interviews
Interview lengths	1–1,5 hours (total 26 hours)	1–3 hours (total 29 hours)
Actors interviewed	Client (11) Design engineer (4) Contractor (5)	Client (7) Design engineer (7) Contractor (10)
Roles interviewed	Project manager, manager, specialist	Project manager, manager, specialist
Observations	Observations of meetings and activities in the Project Office (2 days)	Observations of meetings and activities in the Big Room (5 days)

euros; spanning multiple years from planning to completion; having a major political and societal impact; and involving several organizations (Flyvbjerg 2014, Pollack *et al*. 2018). Furthermore, the public clients of the two infrastructure projects defined them as large and complex. Since there are few such large infrastructure projects in the Nordic countries and only a handful that use a CPDM contract, we were limited in selecting cases that were ongoing and accessible at the time of data collection.

The two cases were viewed as CPDM cases by both the public clients but also by other researchers in the two countries. For both case projects the usage of a collaborative approach was relatively new for the public clients and the clients tested the new model through the projects. The two case studies were divided into a Formation phase, consisting of preparation, procurement and tendering where the client prepares project and tender, and the contractor/design engineer sends in a bid for the tender; Phase 1, which consists of the development of project planning and set-up, pre-design and a cost estimation of a target price; and Phase 2, in which detailed design is done and construction commences. The goal in using a CPDM is that the same team, consisting of client, design engineer and contractor, is involved from design to execution (Phase 1 and 2), thus facilitating knowledge transfer between phases and start-up of construction activities (Lahdenperä 2012, Walker and Lloyd-Walker 2015), which did transpire in the investigated cases. The model moreover includes a high level of collaboration, which occurred in one case.

Case Rail is a new rail-based public transportation infrastructure project in a large Nordic city. The public client has a bilateral and collaborative contract with the contractor in the form of an ECI-contract and the contractor has subcontracted all project moments and partners for both design and construction. The public client is the main and largest client for infrastructure project in this country and has a lot of experience with all types of infrastructure construction projects. The Formation phase started in 2014 and Phase 1 started in 2016. Phase 2 started in 2018. The project is ongoing with an estimated completion date in 2026. The project's finances are based on a target cost and running accounts. The incentive structure offers the contractor staggered bonuses if certain parameters are met during and after project execution. The traditional penalties for delays or deficiencies have been minimised to encourage collaboration and risk is mainly on the client. There is an additional incentive built into the target cost, offering the contractor a predetermined share of the potential savings as a bonus. If the project exceeds the target cost, however, the contractor will only get paid up to a certain proportion.

Case Tram is a new rail-based public transportation infrastructure project in a large Nordic city. The two municipalities through which the rail based public transportation will be crossing are the main two public clients in the project. One of the public clients is a large municipality that previously has been a client for large infrastructure projects, while the second client is a smaller municipality with less experience. The two public clients have engaged in a multi-party alliance contract with two main contractors and two design engineering firms. The Formation phase started in 2016, followed by Phase 1starting in 2018 and Phase 2 in 2019. The project was completed in 2023, before schedule. The project's finances are based on a target cost and running accounts. The incentive structure offers the contractor staggered bonuses if certain parameters are met during and after project execution. The traditional penalties for delays or deficiencies have been minimised to encourage collaboration and risk is evenly shared between the contractual parties and the project works under a no-litigation principle. There is an additional incentive built into the target cost, offering the consortium a staggered percentage of the potential savings as a bonus down to a predetermined percentage. If the cost is even lower than the "floor" of the target percentage, the client gets the remainder of the saving. If the project exceeds the target cost, the client and consortium share the costs 50-50.

Data collection

The empirical corpus of this study consists of 45 interviews and 58 hours of observation, conducted between August 2019 and January 2020. The interviews were semi-structured, supported by an interview guideline and held with representatives of the three main roles of client, design engineer and contractor. Interviews were conducted with respondents from all levels of the project hierarchy and from all main participating organizations. In total we conducted 20 interviews for case Rail, and 25 interviews for case Tram. The respondents were selected in relation to their roles in the project organization with a focus on representing the main contracted parties (representatives of the client, contractor, engineering consultant) and further with snowball sampling from the main project actors. Interviews were conducted until

Table 2. Example of the code structure.

Codes	Themes	Consists of codes:
Formal ties	Contracts and incentives	• Type of contract • Requirements • Incentives, bonuses, penalties • Sharing of risks
	Project organisation	• Project organisational structure, set-up • Decision making hierarchy • Hierarchy • Roles and responsibilities defined. • Tasks defined and divided
	Project processes	• Coordination • Meeting structures • Sharing of information (when and how) • Conflict resolution processes • Collaboration processes (start-workshop, co-location, team surveys etc.)
Informal ties	Social relationships and interaction	• Informal communication • Informal events, social gatherings, social events • After-works, sports events • Perceived collaboration • Previous work-experience/relations between actors
	Project culture and trust	• Culture, how project members perceive the project • Trust in other members, actors

saturation. An additional follow-up interview was conducted with the project manager in case Tram once the project was finished. The first author performed all interviews, and all interviews were taped and transcribed. Notes were taken during all interviews. Interview questions focused on, among others, the development of the project, the collaboration with other actors, the project organization, sharing of resources between actors, and lessons learned. To understand the project's social network, interviewees were asked who they work most with and how often and to describe their relationship. The networks started from the project's project managers. Most interviews were conducted at the project offices, while a few took place in the respondent's home organization's offices. Informality and a willingness to share characterized the interviews in both cases.

We also conducted observations of the shared project office space on or close to the construction site of the two cases for a total of 58 hours. The main purpose of the observations was first, to gain more insight in the formal and informal interactions and collaboration activities between the main actors of the project, second to get context for the project orgnaisation and its daily life, and third to add context to the interviews. Both cases used a shared office space, officially called a Big Room in case Tram. In case Rail the collaborative space was known as the Project Office. We also observed several meetings, which were either ad hoc or arranged according to the project's processes. Observations enabled the identification of day-to-day interactions and informal events not captured in official documentation. For the observations a structured observation guideline was used in which for specific time intervals notes were taken on the actors observed, the activity, artefacts used, and spatial lay-out.

We applied a qualitative approach to provide rich data and understand the nuances of collaborative relationships (Blackburn 2002, Hardy *et al*. 2003). The scope of this paper excludes actor characteristics, such as individual's age, the home organization's field position or their resource access.

In both cases, the project manager provided access to project documents such as the contract, decision making responsibilities, organizational charts as well as documentation from start-up workshops (joint values and goals). In case Tram, the project manager also provided access to other documents, including project survey results, internal meeting memoranda and presentations. The observational data and additional documents were mainly used to add context and triangulate the data from the interviews (see Table 1 for the case description and data collection overview).

Data analysis

For the data analysis of the empirical data open coding was used. In the later stage the coding was related to social network terminology on formal and informal ties (see Table 2) and connected to strength of ties and benefits (functions) and challenges (dysfunctions). The coding process went through a number of systematic stages of naming, data reduction, focused coding and data display (Locke 2001).

These codes followed our research question and were analyzed by first arranging it into concepts and

then into broader themes in NVivo, establishing the full dataset and context of the cases (see Table 2). Observational data such as notes, photographs and sketches were scanned or transcribed and uploaded in NVivo and coded in a similar way as the interviews. Several themes came out of the data, for example, different types of ties and consequences of these ties.

To gain insight in the social network, we applied a qualitative social network analysis based on the interview questions asking interviewees who their closest colleagues were, and which persons they worked most with. Informal ties were identified by combining the interview data concerning the social network with the observational notes. Our definition of strong ties is inspired by Granovetter (1973) as a combination of the time, individual emotional input, mutual trust, and reciprocity of the tie. Based on our qualitative empirical material, we categorized informal social ties as "strong" focusing on the respondent's own judgment, combined with the frequency of interactions.

The social network focused only on the project members who were directly involved in the project and external stakeholders were not included. The qualitative analysis provided a deeper understanding of the network and its ties, and contributed to answer calls for more qualitative network approaches (Hersberger 2003, Steen *et al.* 2018, Loosemore *et al.* 2020). Furthermore, a qualitative approach allowed for a contextual understanding of the social network (Hersberger 2003) in our emperical material. By comparing the network to the tone and phrasing in the respondent's answers, the characteristics of the ties became clearer.

To validate our findings, we discussed them with a reference group, consisting of industry and academic experts in the field.

Findings

In the following section, the two cases are presented in terms of formal and informal ties. Formal ties are divided into contract and incentives, and project organisation and process. Informal ties are divided into social relationships and interaction, and project culture and trust.

Case rail

Formal ties in case Rail

Contract and incentives: The project's contractual framework was based on a request for tender, where the client asked for a contractor who could deliver the whole project through a consortium and a project model based on early contractor involvement (ECI). During this pre-project process in case Rail, the main contractor set up a consortium consisting of the main contractor, design engineer organisation and subcontractors. The main project contract was thus a bilateral one between the client and main contractor (based on the contract documents received from the client and information from the interviews). The contract is a strong formal tie as both actors have agreed on the contractual terms before signing. Due to the bilateral main contract between contractor and client, there was no contractual tie between the public client and the design engineer or subcontractors. According to the client, the contractor focused on the letter of the contract, while the client focuses on the spirit of the CPDM agreement, jointly formulated in the bilateral organization since the contract itself is based on a traditional construction contract. The relationship between the client and contractor was fraught with tension due to contractual disagreements. The client's biggest challenge in this case is the relationship to the contractor and the lack of alignment on the project model:

> Either we [the client] have been very bad at explaining what we want, or [the contractor] does not want to interpret it as we expected
>
> (Client's project manager).

Incentives affected the project, both on an organizational and a personal level. The client lacked power through financial penalties due to contractual clauses and viewed the contractor's personal bonuses as detrimental to collaboration, while the contractor saw the incentives as lacking. There were however also some contradicting views within the client organisation on how the incentives and bonuses worked in practice. Incentives, as part of the procurement and contract, are strong formal ties as they are commonly and formally agreed upon, and direct activities.

Project organisation and process: The project model was new for both the contractor and the client organization, since the connected and sequential project set-up of Phase 1 (design) and Phase 2 (delivery), where the consortium's proceeding to Phase 2 depends on the outcome of Phase 1, is uncommon in Nordic infrastructure construction. The client mentions that their processes are not fitted for this new model, as exemplified by the following quote:

> Already from the beginning you could say- we noticed that quite a lot of our regulations and documentation practices are built on … during phase 1, we had- I am using the word 'ECI agreement' because it's not really a contract. The contracts have been standard contracts. But the procurement process is a bit different when you tender for standard

> contracts. And our directives, our regulations … everything we are used to be doing, they are not adapted to this ECI-model. And that's what I mean with that we notice we have been the first ones [to implement ECI].
>
> (Client's project manager)

The project was organised as mirroring project organisations between the main contractual partners, where the client and the contractor created separate project organisations organised according to the same structure. Authority and decision-making power were divided and allocated according to the home organisation in the mirroring organisations. This could lead to challenges if one organisation lacked the mirroring role.

The project process was divided into phase 1, design and development, and phase 2, construction. Formal discussions between client-contractor-design engineer as well as document and information sharing went through the contractor. The designs were developed by the contractor's consortium in phase 1. During phase 2, when detailed planning commenced, several flaws and mistakes were uncovered. The client viewed this as the contractor's responsibility, since they had drafted the general plans in phase 1, while the contractor argued that the client had accepted the plans when the project moved from phase 1 to phase 2 and were thus responsible for the newfound issues. The client chose the two-stage model to avoid the administrative burden of checking designs and as a result of the project's conflicts and lack of progress, the client's home organisation is now re-evaluating the use of CPDM.

During Phase 1, the relationship between the contractor and the client was strained, partly due to the uncertainties of the model and partly to the scale and complexity of the project, as well as a lack of common understanding of the project model, contract and content of Phase 1. This was still visible in Phase 2 when delivery works started. Complexities and uncertainties surrounding the project further increased tensions, especially since the project budget was strained, leading to contractual conflict between the client and contractor.

The overarching project organisation was thus a weak tie, as the stronger organisational ties occurred within the actors' own organisations. The project process was also a weak tie, as the actors had differing views on the set-up and the responsibilities during the process.

Informal ties in case Rail

Social relationships and social interaction: The contractor and design engineers formed strong social relationships during the tendering phase. They also had earlier experience from working together, which was remarked as a beneficial aspect. The strength of the relationship between the design engineer and the contractor was described by a contractor representative as *"it's the third project in a row we are working together, of course we have gotten to know each other"*. However, the social relationship between the contractor and client was negative and between the design engineer and client non-existent. According to one of the design engineers:

> We worked really intensely together with [the contractor] during the tendering stage. So, when we got there [to the project], we were a really tight team. And there we – now that I look at it in hindsight, we should have understood how strong a team we were. We didn't get [the client] on board. Or it was a challenge for [the client], I think, to be a part of [the team].

The client was also held at arm's length from social gatherings due to internal policies regarding participation in entertainment offered by the service provider, which impacted the formation of social relationships.

The client and contractor were both seated at the shared project office, where the space was divided according to organizational affiliation, with for example separate meeting rooms and seating areas for both organisations. Based on observations, during coffee breaks and lunch, people mainly interacted with the colleagues seated closest to them or with people from their home organisation.

The design engineers were not located at the project office on site, and mainly worked from their home offices and only came to the joint project office for meetings (based on the interviews and observations). This was a challenge for spontaneous interaction to occur, as most of the other key individuals from both the client and the contractor sat at the project office.

The design engineers viewed the project as traditional but could not say whether it is "because everyone is used to working like this or if we just fell into familiar patterns" (design engineer, project manager). The design engineers work with their client, the main project contractor since their contract is with them rather than the public client. The design engineer thus cannot have direct contact with the project client, necessitating multi-party communications when they need to discuss design decisions. This was viewed as a proper communication path due to the contractual relationships but could lead to delays in the communication pathways. For example, schedule changes were not communicated to the design engineer who then lacked information on changed priorities. The lack of

collaboration within the larger project led to trench-building between the actors, cementing differences both through the current organizational set-up and previous working relationships. The contractor and design engineers were closely connected and worked well together. However, the client representatives were hardly connected to other project participants and mainly interacted with the project managers. They moreover had little to no connection with the design engineers in general, although the design team became a mediator in the project. Most viewed the project as a traditional project, although the collaborative approach was perceived as having potential.

Project culture and trust: Although the atmosphere in general was good, there was no unified project culture and the actors did not share an understanding of responsibility in the project or of the project process, as exemplified by the aforementioned conflicts surrounding the designs in phase 2. The lack of alignment on the project process has increased the tensions in the project organization. Both the client and contractor describe the project culture as an us-versus-them feeling. Several members of the contractor firm identified group formation in the project, isolating the client and the contractor from each other. As described by a production manager from the client:

> The atmosphere is good, in my opinion. But it's a bit too much of "you against us" or "us and them" or what have you. It could be better, and I think it would be better if you'd agree on what ECI actually is because there– we are a long way from each other.

All respondents identified more strongly with their home organization than with the project organization. They moreover viewed trust as minimal or non-existent in the project. This was partly based on the conflicts surrounding the contract and part of the problem was traced back to the client's use of hired consultants rather than their own employees as this reduced the mandate in the project.

> If you want people to act freely, you need to give them the mandate and then back them up in the decisions they make. But you can't do that with someone contracted. […] You have to have enough people to do the task – and you need to have the trust to do the task. But a contracted consultant can be replaced tomorrow. And … is that really trust-building?
>
> (Design engineer, manager)

Project culture and trust were thus weak ties, since the actors lacked a common understanding regarding them. Moreover, collaboration in the project organisation was seen as very negative and the participating organizations as separate siloes without much inter-organisational collaboration. The design engineers were especially laconic regarding the collaboration in the project.

The lack of collaboration was described in the same term by all actors, as exemplified by a manager from the contractor:

> And the collaboration that people talk about … I wouldn't say it's collaboration, except perhaps within the group for working environment, there we do have collaboration, but in general I don't think we have it. Collaboration for me, that's when you help each other.
>
> (Contractor, manager)

Table 3 summarizes the main findings for case Rail.

Case tram

Formal ties in case tram

Contract and incentives: In case Tram, the actors entered a multiparty contract (data came from the formal contract documents as well as from interviews) in which the formal contractual tie was between the main project participants (two client organizations, two design engineer firms and two contractor firms). The model was new for most of the partners and required some adjustment for most of them, but especially for the client organization.

> And in my opinion, the one with the most to learn from this [CPDM model] is the role of the client. Maybe the contractor and design engineer are more used to mutual cooperation, but having the client as part of it and the client often has a problem with … those [at the client organisation] who have been working at the contractor, those quite easily resort to telling people that "we're doing this and this and this" and then they don't listen to what others have to say. So true listening, true collaboration, that can be difficult for the client.
>
> (Client, project manager)

The financial incentives were seen as enabling task-focus and freeing up resources from discussing the contract. Due to the commercial model, several people changed organizations to be able to continue working at the project. One of the contractors saw this as causing tensions between the home organizations; they had agreed on "anti-poaching" policies between themselves when they set up the project, but since the budget hindered specially design engineers from participating due to their financial models, this incentivized people to change employers rather than leave the project, reducing personnel

Table 3. Findings for case Rail.

Case Rail	Tie strength	Function and challenges
Formal ties		
Contract	The contractor has strong formal ties with the client and design engineer, but no formal tie between client and design engineer	• Clear specification of requirements • Contract type benefits two parties, leaving one party outside the strong tie - contractor is the formal link between client and design engineer
Incentives	The contractor has strong formal ties with client and design engineer	• Clear specification of incentives and risks in formal tie • The tie between contractor and client has a strong focus on incentives and how to share risks and costs (focus on letter of the contract) • The tie between contractor and design engineer is a combination of formal and informal ties.
Project organisation	Contractor has strong tie with design engineer and clear project organization. The tie with contractor and client is weak and parties view organizational responsibilities differently	• The project organisation mirrors the home organisation of the client and contractor creating separate structures • Client and contractor have different views on responsibilities and tasks • Project organisation new for client and contractor and processes not fitted for the delivery model. • Actors have strong relations with their home organisation, less strong with project partners
Project process	Contractor has weak formal ties with client, but stronger ties with design engineer	• The client processes do not fit for CPDM projects • There was lack of understanding between client and contractor on project process creating tensions and conflicts • Ties between contractor and design engineer strong, they followed traditional project processes well-known to them
Informal ties		
Social relations	The contractor has a strong informal tie with the design engineer, but a weak informal tie with the client. There is no informal tie between client and design engineer	• The strong informal tie between contractor and design engineer is based on reputation and earlier experience of working with each other • The weak tie between client and contractor and no tie to design engineers leaves the client outside social relations and social events
Project culture and trust	There are weak ties between client and contractor related to trust and culture	• All actors have a strong identification with their home organization – there is not a common project culture. • Power differences between in-groups with strong ties versus those outside (e.g. client) and there is an us-versus-them feeling (leaving out some actors)

turnover. The commercial model and incentives were moreover regarded as functioning and reducing conflict within the project. The contract and incentives were thus strong formal ties. As the client's project manager said:

> Within the project it has been crystal clear how the money is divided, which pot the money comes from and then we react to outside challenges and threats by solving the technical tasks together and we don't have to think about who's responsibility this is or isn't. So that's by far the biggest benefit.

There were however power differences between especially the two contractor organizations and client organizations, mainly tied to size but also, in the client organisations' case, to previous interactions. The smaller organisation felt like they were simply there for the ride and couldn't much affect the project, for example in terms of which processes or tools to use. Respondents from the smaller contractor organization saw the organisational interaction as if they had to accept most things dictated by the larger contractor organization, such as which processes and tools to use. Respondents from the smaller client organisation remarked on the historical tensions between the two clients. The design engineers did not remark upon power differences, but their home organizations were comparable in size and field position. However, the project in general had a strong collaborative spirit, which led them to view problems as one team with one goal. The two design engineering organisations were of similar size and prominence.

Project organisation and process: The two client organizations selected the design engineer firms and the contractor at different occasions to be able to separately choose the best candidates. The clients chose the design engineers first and during the early development phase of the project (phase 1), the client and design engineer started to work on the project organization and planned the process. The contractor was selected later in the process and

came onboard approximately two months after the design engineer organization. The contractor had initially a weaker connection to the clients and design engineers and according to one of the clients:

> It probably turned out to be the wrong decision in the way that– because we had fewer builder resources available – it didn't allow for such a comprehensive design-builder collaboration as probably would have been needed to really reap the benefits from [the CPDM].

The project set-up and early stages also led to disagreements. First, the initial project routines and sub-division of the project into design blocks as set up by the client and design engineers did not match with contractor needs. The contractor re-divided the project according to their needs, leading to overlap and fragmentation within some design blocks. Second, the division partially divided the project organization into siloes, especially in phase 2, as construction commenced and the blocks became more independent from the main project office, dispersing into block offices. Moreover, the delay in moving from phase 1 to phase 2 led to challenges in the contractor's organizations since people became attached to other construction sites.

The dual client organizations made for a challenging starting point for the project and the existing relationship between them shapes the whole project, which made aligning project and client goals difficult. For example, in a recent steering group meeting, "*no-one from [the smaller client organization] said a word during the entire time, when everyone was gathered*" (expert, contractor).

The project had a core collaborative team, a periphery of part-time project participants and people nominally attached to the project. Within the inner, full-time core team, mutual understanding had increased throughout the project through enabling insight into each other's work although this was dependent on personality and character. The early-phase goal alignment and risk allocation had also contributed to a mutual understanding.

According to the client, the main governing challenge came from the sheer size of the project as the dissemination of collaborative practices to hundreds of people located at different sites, both at the project and at their home organizations, was difficult at best. The high degree of physical presence at project offices, however, alleviated this issue and participants consequently lamented the loss of day-to-day interaction during the lockdowns and work-from-home policies necessitated by the Covid-19 pandemic in March 2020.

Turnover and the inherent temporality of the project created another challenge. The natural turnover in such large projects accentuates the role of continuity and processes for information management, "*because if something is merely in the head of one individual, there'll be trouble when that person leaves*" (project manager, client). The turnover also leads to a constant fluidity in project roles since the tasks are rearranged according to the person in the role so "*the organization is in a constant state of change*" (project manager, client) and new members have difficulty entering the existing social network.

The project organisation and process were in general strong ties, with a high degree of mutual agreement, even though the process had experienced challenges.

Informal ties in case tram

Social relationships and spontaneous interaction: The social relationships within the project were in general viewed in a positive light and the network was highly connected. The project was viewed as one organisation and people like their colleagues. However, respondents did see the need for both the right collaborative mindset for successful project participation as well as challenges in forming social ties over organisational and professional boundaries. As a manager from the design engineer stated:

> They do work a bit in their own [organisational] teams but it's so much easier for a design engineer to talk to a design engineer than to a contractor. There is a significant difference. Even though, even if we are from different organisations, the tasks and roles are very similar. And we are doing the same things in that project as well, just over many kilometres. The place is a bit different, but it's the same things so … design engineers get much better along together than with the contractor. And I'm sure it's the same the other way around. That the contractors get better along than with the design engineers.

This was also visible in their relationship with the client, since the design engineer and client were both used to the same sort of processes and practices, especially in phase 1, while the iterative process was new for the contractor.

Individual attitude towards collaboration and "personal chemistry" was seen as a major factor in the creation of collaborative social ties in case Tram as mentioned by all actors. Most respondents saw the project as well functioning and highly collaborative in general, with social gatherings outside the project office such as sports games exemplifying the high

levels of social relations and collaborative spirit. As one respondent from the designer put it:

> In many projects you can sidestep the question about "personal chemistry" but in this [collaborative] process, I think it has a surprisingly large role if we get along.

However, the contractor and design engineer clashed at the start of phase 2. According to the client, the differences between contractors and design engineers, who view the situation from opposite sides, result in the biggest challenges: "*the contractor says it was agreed and the design engineers says it was dictated*". The conflict depended partly on a lack of collaborative practices, "such as honest discussion" (client representative). To enhance collaborative practices, the project had instated several collective tools, such as risk management software, scheduling tools as well as document management systems and procedures. Tensions created by the early project set-up by the client and design engineer were visible in the conflict between design engineer and contractor whose needs were not met by the initial organization design.

Previous relationships and preconceived notions also had an impact, both on individual and organisational levels. In case Tram, there were two public clients involved. According to one of the client representatives, previous relationships between the two client organizations were one of the greatest challenges. Although they collaborated well within case Tram, historical tensions as well as size differences between the client organizations permeated the project. For example, several of the steering group members from the client organizations had been part of a recent infrastructure megaproject that had gone over budget and schedule, to the disadvantage of especially one of the client organizations. This had led to delays in the project schedule due to an increase in the target price at the end of Phase 1, as both client organizations needed to reaffirm their earlier commitment and some in the project felt that the smaller client organization deliberately slowed down their decision-making process. For the public client organizations their home organization could be challenging and especially for the smaller client organization, the decision-making processes in the home organization could be slow and could stall project decision making. This was seen by the larger client as negative to the project. Thus, strong (negative) social ties affected the formal framework of the project.

Based on interview and observation data, people gathered at daily coffee breaks near the coffee machine at pre-set times and informal social media groups and social events, such as summer and winter parties, gathered people for social interaction. The respondents felt it was easy to reach out to anyone in the project, also people they had not met before, and that the organisation of the co-located project office helped in facilitating spontaneous meetings – although the office could become too noisy for tasks requiring focus and concentration. The design engineers' division of the project into geographical blocks curbed inter-organisational interaction, although they did gather at design meetings and at the co-located office. The social ties were mainly strong within the core project team and weak with the home organisations.

Project culture and trust: Project culture and team spirit increased throughout the project and visitors at the collocated space have remarked on the bustle and activity found there, although there are also some negative aspects highlighted with the co-located space. For example, not all project members were constantly present in the project space and some members were only present for a few days or sometimes hours per week, leaving these actors outside the emergent informal social network and making their collaborative efforts harder.

Interviewees viewed that the level of trust within the project was in general high and seen as dependent on the personality types involved in the project. An initial absence of trust has improved throughout the project, although rectifying it has required a substantial commitment of both time and resources. The scale of the project further complicated trust-building as the number of participants increased the number of necessary trust-ties.

On an organisational level, people were trusted with their work tasks and the inter-personal trust was high. However, doubts regarding organisational trustworthiness did arise, especially from the contractor regarding the design engineer. As a project manager from the contractor said:

> I have a slight suspicion, or a fear, that the design engineers are overbilling. And that's why they don't want to put those designers out in the field. I can't say if it's really the case. But there has to be some reason that they don't want to go there. They themselves say that it's because of bad internet connection and a lack of colleagues of whom to ask things. But in my opinion, it's more … they don't really go and ask [their colleagues] personally, they call or use [virtual meeting platform]. It can't be the reason that the design engineers don't dare to be at [the site].

Table 4. Findings of case Tram.

Case Tram	Tie strength	Function and challenges
Formal ties		
Contract	There are strong formal ties through a multiparty contract between all project actors	• The formal ties related to contract reduce conflicts, clarity of rules, incentives • people change organization over time to stay in the project causing tensions between actors
Incentives	There are strong formal ties through a multiparty contract between all project actors	• Clear incentive structure in contract • Enabling task focus and freeing resources
Project organisation	There are strong formal ties between clients and design engineers in the project start up. The ties with the contractor are weaker in the project startup.	• The project organization provides a clear division of tasks and roles of the core team over time • Initially in project start-up, the client and design engineer set up the organisation, leaving out the contractor
Project process	Strong formal ties between the actors concerning project processes	• The project core team defines collaborative processes and practices • Size of project hinders implementation of clear process and coordination is complex • Turnover challenging with new people difficult to get in the existing strong teams
Informal ties		
Social relations	Strong informal ties between partners, project viewed as highly connected	• Strong social relations within the project, social gatherings, co-location • Previous relationships impact the relations of the two clients negatively • Ties contractor and design engineer are weaker • Weak ties with home organizations • Difficult for newcomers to enter existing teams with strong ties.
Project culture and trust	Strong informal ties, common project culture	• Project is seen as one organization • Actors not part of the co-location are left behind

Table 4 summarizes the main findings of case Tram.

Discussion

The aim of this article was to investigate the interplay between formal and informal ties in two infrastructure delivery projects based on a CPDM. To that end, we have explored how collaboration in a CPDM can be understood through the interrelation of formal and informal ties and their (dys)functions.

Although the formal and informal frameworks have been seen as complimentary (Poppo and Zenger 2002, Papadonikolaki *et al*. 2017, Biersteker and Marrewijk 2023), the implications, consequences, interaction and the strengths of these ties in relation to CPDM projects have been underexplored. Further, while both the relevance of the procurement phase and contractual mechanisms have been identified in previous literature (Poppo and Zenger 2002, Eriksson and Laan 2009, Chen *et al*. 2018) and the social network perspective has shown the intricacies of social ties (Pryke 2012, Papadonikolaki *et al*. 2017, Matinheikki *et al*. 2019), very little research has been devoted towards discussing in-depth the different forms of formal and informal ties in interaction.

We contribute to the discussion on contractual and relational governance, particularly, the challenge of balancing formal contracts and informal relationships in large projects (Fang *et al*. 2024, Roehrich *et al*. 2023). In line with this literature, we show how a inclusive formal contract between participating organisations enables the formation of strong interpersonal relationships between key actors in the project organisation. Our results present new insights on the challenges of formal and informal ties, especially in long-term construction projects such as infrastructure delivery. Our findings propose that strong formal ties of contract, incentive, project organisation and process can influence the creation of an informal network, consisting of social ties and interaction, trust and project culture, while informal ties may impact the perception of formal ties. We also illustrate a challenging project situation, where an excluding contract weakens the interpersonal relationships, and hinders efficient communication within the project.

Interaction between formal and informal ties in infrastructure IOPs

Consistent with previous research (Poppo and Zenger 2002, Papadonikolaki *et al*. 2017, Wang *et al*. 2018),

our results propose that the strong formal framework created by the contract and incentives, directed the creation of informal ties within the project networks. Further, in line with Poppo and Zenger (2002) and Wang *et al*. (2018), we show the complementarity of the formal and informal frameworks. Moreover, we highlight the importance of the development and interaction of these.

The strong formal tie of the contract, acting as the organisational basis for the project directed the project organisation and processes (Wang *et al*. 2018). In contrast with previous literature focusing on how social networks, and thus individual interactions, impacts project outcomes (Zheng *et al*. 2016, Wang *et al*. 2018) as well as the impact of both the institutional level (Wang *et al*. 2018) as well as specific tools (Papadonikolaki *et al*. 2017), our research show consequences of how individual attitude, expectation and collaborative aptitude influences how the formal tie was interpreted. As the two cases display, the formal ties brought together the actors, while their interpersonal and inter-organisational dynamics shaped how they interpret and implement formal ties.

We contribute to the discussion on governance aspects related to formal and informal aspects for interorganizational infrastructure construction projects (e.g. Nilsson Vestola and Eriksson 2023, Bygballe *et al*. 2015), by studying the interaction between formal and informal ties and consequences of the strength of these ties for the project. Our empirical results provide additional insights into how these governance aspects are important in shaping the project's network, as well as how their interaction contributes to the development of collaboration as the result of a continuous cycle of interaction between formal and informal governance or practice. Both formal and informal ties are thus important in shaping the project's network, but it is their interaction that creates the development of collaboration over time. However, we also point to the challenges of strong formal and informal networks, especially over time and the consequences for the project organisation thereof.

Consequences and challenges of the strength of ties in infrastructure IOPs

A strong tie is understood and accepted by both parties, while the nature of a weak tie changes depending on the beholder. A friendship exists only if both parties agree to it, for example, and a formal contract exists only if both parties agree to its terms. Consistent with previous studies (Burt 2001, Battilana and Casciaro 2012), our results indicate that weak formal ties introduced new knowledge into the project's network. However, they also challenged other strong formal ties which consequently weakened over time, especially when weak formal ties were combined with strong informal ties. In the case Rail, for example, a weak project organisation with fragmented responsibilities weakened the understanding of the contracts and incentives (a weak informal network), and thus, affected the entire strong formal contract tie. In case Tram, a strong informal network within the project led to the partial exclusion of non-network actors introduced through weak formal ties, thus partly acting as a barrier to the wished-for introduction of new knowledge and resources. Moreover, as earlier strong (negative) informal ties led to conflict and delays at the end of phase 1, a strong network is not merely beneficial for the project.

Our findings also show two main challenges linked to previous research on relational governance and CPDM that builds on the benefits of strong social relationships such as trust, quick communication paths and decision-making (cf. Walker and Lloyd-Walker 2015, Bygballe and Swärd 2019, Nwajei *et al*. 2022). As our result demonstrates, first, a strong formal network can act as a barrier for strong informal ties to form when either the formal ties are misaligned or the right collaborative attitude is lacking. Second, too strong informal networks becomes a barrier to entry, especially to actors who are introduced through weak formal ties. This is particularly challenging in long-term projects, where individual actors are expected to change during the project and even organisational actors can change. The strong informal networks hinder actors connected to the project by weak formal ties from participating in the project, thus restricting the network and curtailing this expected actor exchange.

Although strong formal ties offer coordination (Klein-Woolthuis *et al*. 2005, Howard *et al*. 2019), support constructive task-related discussions or disagreements (Zeng *et al*. 2022) and improve decision making (Jehn and Mannix 2001), our findings indicate that dysfunctions of strong formal ties can lead to lack of flexibility, homophily, increase of conflict and disagreement as well as a risk for adversity (see Table 5 on the functions and dysfunctions of strong formal ties). However, as our results show, a common understanding of the formal framework develops as the project progresses, and a unified culture is created in combination with a strong project-wide informal network.

Table 5. Implications of strength of ties for infrastructure construction projects, their function and disfunctions.

Ties	Functions	Dysfunctions
Strong formal ties	Clear contract, coordination and control Clarification of roles and responsibilities	Homophily Risk for adversity – only focus on incentives and contract details Can lead to conflict when the project organisation and processes are not aligned with the CPDM and party's expectations
Weak formal ties	Challenge the status quo of the project organisation and bring in outside information and resources	Misunderstandings and unproductive task conflicts can arise when formal ties are not aligned with project's vision and goal
Strong informal ties	Trust Information sharing Close informal relations (social events, cohesive project culture) Enable resource sharing between actors	Us-versus-them feeling (leaving out some actors) Difficult for new actor to get into a strong network Power differences between in-groups with strong ties vs. those outside
Weak informal ties	Introduce new information Bridge between the project's social network and other communities	Tensions and conflicts Less information sharing Less trust Focus on home organisation than project organisation

Weak formal ties can challenge the status quo of the project organisation by bringing in outside information and resources. However, misunderstandings and unproductive task conflict can occur if the weak formal ties are not aligned with the project's vision and goal (cf Jehn and Mannix 2001).

Our findings demonstrate, in line with prior research (e.g. Buvik and Rolfsen 2015, Papadonikolaki *et al*. 2017, Hietajärvi and Aaltonen 2018), how strong informal ties enable trust, information sharing, a unified project culture and goal alignment (Table 5). Implications include the exclusion of outside, or new, actors and an us-versus-them feeling, as well as power differences between in- and out-groups (McPherson *et al*. 2001).

Weak informal ties can give new insights to boundary spanners but restrict information sharing and can lead to tension and relational conflict if the connection to the project organisation and its informal network stays weak.

Thus, our findings reveal that a strong formal tie can be a barrier to develop strong informal ties as in case Rail. However, a strong informal tie can also be a barrier for new entrances or parties left outside the strong informal tie, which is exemplified in case Tram. In line with earlier research (Howard *et al*. 2019) on the functions and dysfunctions of governance between two parties, these challenges can develop over time, entailing that a strong formal/informal tie can be beneficial to certain parties but dysfunctional to other parties. This finding completents research from Fang *et al*. (2024) on the unintended side effects of the interplay of formal and informal governance, where our research focuses more on the dysfunctions arising from strong ties.

An overview of this discussion is shown in Table 5.

Conclusion

This study aimed at investigating the interplay between formal and informal ties in two infrastructure delivery projects, utilising a collaborative project delivery model. Using a social network approach as theoretical lens, our results suggest that the interaction of formal and informal ties is a cyclical development. The formal ties as defined by the project contract and the formal ties originating from it establish a framework for the informal network to grow. The informal network can, however, influence how the formal ties are interpreted and thus either strengthen or weaken the formal ties, depending on the project actors and their characteristics. Furthermore, as our findings show, a strong tie (formal or informal) is not always positive but can be a barrier for collaboration and other tie development in CPDM projects. Finally, we discuss that these challenges or dysfunctions of strong and weak formal and informal ties develop over time and a strong formal/informal tie can be beneficial to certain parties but dysfunctional to other parties.

We advance our understanding of tie interaction within the project network due to the detailed data about how the formal and informal ties are construed by actors and how they influence each other. It provides new input into the discussion on the interaction and fit of informal and formal frameworks. For practitioners, the findings on the interplay between ties emphasises the importance of creating a formal framework, which supports the formation of strong informal ties in order to achieve relational governance, rather than focusing on only the formal ties and contractual governance.

Limitations and future study

This study has three main limitations: its geographical scope, the method, and type of projects studied. The similar context of our studied cases facilitate comparison as they are both located in the Nordic context. However, this also limits their generalisability. Future studies could look at similar projects in other geographical locations to test our findings on the interaction of ties. Second, the case study method, although providing deep insight into the specific case, may limit generalisation to other contexts. Future research could be conducted on larger datasets or look at how similar projects develop over time as a longitudinal study. Third, the study focuses on the infrastructure construction industry, which is characterised by multiple stakeholders, a public context and long-time spans. The findings may therefore not be as applicable to other construction projects, such as building design. Studies in adjacent fields, such as building construction or development of other sorts of transport infrastructure could give further insights into network ties in construction projects.

Previous publication

This paper is originally based on a conference article titled "The dark side of collaboration: The risks of strong ties in collaborative project networks", presented at the Association of Researchers in Construction Management Annual Conference in 2021. However, during the revision processes, the paper has developed fundamentally.

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