



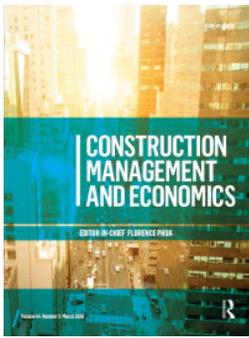
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Cross-industry innovation: exploring the dynamics of an innovation network in construction

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ABSTRACT

Innovation in construction is a complex, collaborative effort. While inter-organizational collaboration is essential for overcoming project-based constraints, cross-industry collaboration necessitates knowledge and resources from technically proficient organizations to co-create innovative solutions tailored to construction needs. This paper explores how a collaborative innovation network evolves across industrial actors involving the construction industry and the automotive industry. Using the Industrial Network Approach (INA), this study explores the dynamics of an innovation process for co-creating a digital application called the “Efficient Load Out”, which tracks and optimizes truck loads. Data was collected through 16 semi-structured interviews with the main contractor, subcontractors, and a truck group conglomerate. The results show that the dynamic nature of network interdependencies in cross-industry innovation calls for various features of interaction among the actors in efforts of combining resources and linking activities. The interaction among actors evolve, organizational interfaces and actor roles shift across the initiation, development, pilot, and scale-up phases of the innovation process. The study contributes by showing insights into the dynamic features of context dependency in a cross-industry innovation network, including how an innovation plays out differently for the actors, both on short-term and long-term basis.

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Cross-industry innovation; collaboration; industrial network approach; interaction; interdependency

Introduction

Over the last few decades, innovation has been shown to be a notable area of construction management research (Winch 1998, Winch 2003, Bygballe and Ingemansson 2014, Larsson *et al.* 2022, Wang *et al.* 2023). Innovation can be seen as something new that is implemented and utilized, that is novel to the organization developing it, to improve a process, product or system (Slaughter 1993, 1998). Innovation in construction can have positive effects, for instance, cost reductions, acceleration of construction time, improvements in quality and safety, increased technical feasibility of a project, and competitive advantage (Julison *et al.* 2017). According to Wang *et al.* (2023) construction innovation in project settings can be seen as addressing collaborative engineering problems that cannot be solved by a single actor and therefore require the involvement of multiple actors (Winch 1998, Bygballe and Ingemansson

2014). Previous research has identified that, in the construction industry, relationships and collaborations between practitioners play a major role in stimulating knowledge flows and innovation (Blayse and Manley 2004, Sergeeva and Duryan 2021). Eriksson *et al.* (2017) underscore the value of integrating diverse knowledge sets from multiple actors and define this as an interactive co-creation practice that enhances joint adaptation and incremental development in a project setting. Thus, an active engagement of various actors, including suppliers and customers in a project, plays a crucial role in fostering collaboration for innovation (Ozorhon 2013, Dekker *et al.* 2019) that requires not only managing formal agreements but also encouraging collaboration and learning between organizations (Gadde 2020). Such collaborative ties in an inter-organizational context foster learning and knowledge transfer for innovation between organizations. However, to address the long-standing issue of challenges with innovation

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due to temporality and fragmentation in the construction industry (Vosman *et al.* 2023) not only is inter-organizational collaboration essential but a further step is required to collaborate across industries to drive innovation and facilitate innovation related knowledge to flow across industries (Reichstein *et al.* 2005, Valkokari *et al.* 2024). Cross-industry innovation (CII) commonly refers to the creative imitation and retranslation of existing solutions aiming to meet the needs of other industries, but can also be the development of new solutions where two (or more) parties from different industries collaborate (Gassmann *et al.* 2011, Carmona-Lavado *et al.* 2023). Carmona-Lavado *et al.* (2023) identify that cross-industry innovation is especially relevant in the context of increasing digitalization, and cross-industry innovation studies cover many industries, for example, the automotive industry, chemicals and electronics. But, with a few exceptions (e.g., Enkel and Mezger 2013), studies of cross-industry innovation involving the construction industry are rare. Moreover, the social and organizational contexts in which the innovation is located need to be considered, acknowledging that innovation is a dynamic process where relations between the actors, and between the actors and technical artefacts, change over time (Harty 2008, Bygballe and Ingemansson 2014). Studying the dynamics of an innovation process thus requires an approach that can capture the continuously changing and developing features of an innovation network consisting of different actors and resources relevant to the success of the innovation (Dubois and Gadde 2002a, Duodu *et al.* 2024). Accordingly, for cross-industry innovation it becomes relevant to study how innovation is perceived in the different industrial contexts and how the dynamics of implementation unfold for the different actors. Therefore, we apply the Industrial Network Approach (INA) as a theoretical lens to scrutinize how interdependencies, interactions and relationships form the prerequisites and outcomes of innovation processes, including the perspectives of the different actors involved (Håkansson and Snehota 1995, Håkansson *et al.* 2009, Håkansson and Snehota 2017).

In previous studies applying an industrial network approach to study construction innovation (Bygballe and Ingemansson 2014, Bygballe *et al.* 2015, Havenvid *et al.* 2019), multiple actors or organisations are addressed; however, these studies focus only on the construction industry actors. What remains underexplored is the collaborative aspect of innovation development that occurs across different industries, i.e., cross-industry innovation, of which the construction industry is one industry. Another inadequately

examined aspect is the dynamic changes in the innovation network throughout the collaborative innovation development process. There is also a call for studies on how the innovation is used beyond the setting of where it has been developed and implemented (Havenvid *et al.* 2019). Accordingly, the research question addressed is how a cross-industry collaborative innovation network evolves in a construction setting. Consequently, in the current paper, we conceptualize collaborative innovation between actors representing the automotive industry and construction industry in a co-development initiative of a digital application known as “Efficient Load Out”. The digital application was developed and tested in a major Swedish public infrastructure project involving large-scale transport of excavation masses. The application remained strategically essential beyond the project as part of continued business development. Drawing on the Industrial Network Approach (INA), the study focuses on examining the dynamics of the innovation process due to interactions and interdependencies in the cross-industry innovation network and the following scaling up of the digital application.

Theoretical background

Collaborative innovation in construction

Construction innovation is said to be nonlinear and complex due to the nature of special resources required and invested in producing unique products in projects (Ozorhon 2013). Previous research on innovation in construction has stated that innovation is specially challenging for project-based organizations, e.g., a construction contractor organization (Tatum 1989, Nam and Tatum 1992, Slaughter 1993, Slaughter 2000). Projects can be referred to as temporary networks where the involved actors do not have any joint plans beyond the project (Dubois and Gadde 2002a). While a temporary network can develop new solutions for unique project problems, Håkansson and Ingemansson (2013) highlight the difficulty of applying knowledge from one project’s novel solution to subsequent projects, thereby establishing the new solution as an innovation in use beyond the project. The challenge with innovation in a temporary network is that customized innovative solutions, as per client’s requirement in a one-off temporary project setting, tend to provide outcomes that remain project specific only (Larsson *et al.* 2022). Others discuss that a more radical innovation affecting components and organizational linkages is considerably complex and difficult to implement and diffuse (Slaughter 1998). While this is often

the case, Harty (2008) advocates for a more nuanced approach since the innovation plays out differently for the actors involved. Accordingly, implementation of the same innovation generates different challenges and outcomes for the actors, not only due to the characteristics of the innovation itself but also accounting for the contexts into which it is implemented, i.e., relative boundedness of innovation.

A major source of innovation opportunities is inter-organizational collaboration (Satheesh *et al.* 2024). This is true for the construction industry as the experience and knowledge by many of the actors from various organizations are used for solving problems that can lead to innovative solutions (Harty 2008). However, studies show that especially for tackling new demands such as digitalization and climate reporting, and remaining competitive in the industry, not only inter-organizational collaboration is essential, but also cross-industry collaboration becomes particularly vital (Melander and Pazirandeh 2019). Shi and Xiao (2024) suggest that cross-industry innovation networks improve collaborative innovation performance, emphasizing the necessity of partnerships and the impact of network configurations. Three main types of cross-industry innovation (CII) are identified (Carmona-Lavado *et al.* 2023): inbound, outbound, and coupled. Inbound CII occurs when an organization in one industry faces a problem and searches for a solution in another industry to reuse it. Outbound CII comes about when an organization in one industry has a solution and approaches potential users and customers in another industry. Finally, coupled cross-industry innovation takes place when organizations from different industries jointly innovate to solve a problem or adapt a solution (Carmona-Lavado *et al.* 2023). The various types of cross-industry innovation have implications for the organization and governance of the innovation process. This brings us to address the actor roles in the innovation process.

The role of actors in the cross-industry innovation process

In the context of the construction sector, client organizations are often acknowledged to play a key role in promoting innovation (Vennström and Erik Eriksson 2010, Kulatunga *et al.* 2011, Lindblad and Guerrero 2020). Moreover, while clients can foster innovation through their requirements, the innovation process must involve other actors (Havenvid *et al.* 2016). Research also demonstrates that contractors can be a significant source of construction-related innovation

(Slaughter 1993, Bygballe and Ingemansson 2014). Regarding the role of contractors, research shows that although the importance of collaborating with others, for example, suppliers, is recognized, contractors are more concerned about engaging own employees to come up with new solutions (Bygballe and Ingemansson 2014). Furthermore, while the construction innovation literature acknowledges the importance of inter-organizational collaboration, this body of work largely focuses on innovation within the construction sector itself, paying limited attention to the involvement of external actors or the potential for cross-industry collaboration. For example, Slaughter (2000) discusses various roles for construction companies in the implementation of a construction innovation process. In the early phases (identification and evaluation in the idea phase) construction companies can take on roles like idea generators and gate keepers, in the commitment phase a “champion” can shepherd the innovation and promote the innovation, while in the preparation for implementation a project leader can coordinate resources and activities in line with the project. In the use phase, Slaughter (2000) discusses the role of a coach to guide, train and support internal resources for diffusion. In other construction and innovation literature the champion role does not only present itself in the commitment phase but also in other phases of the innovation process to facilitate inter-organizational collaboration, which includes informal communication and interpersonal coordination (Sergeeva and Zanello 2018, Melander and Pazirandeh 2019). Thus, innovation champions can influence organizational learning by managing internal and external knowledge flows (Drechsler *et al.* 2021). In particular, having one responsible party, actor or organisation to coordinate and integrate the process of innovation is essential (Gadde and Dubois 2010). All in all, the roles of actors in terms of the functions they are assumed to carry out and their behaviors in different phases of the innovation process are often examined within one organization or a single project and are less discussed for cross-industry innovation. In cross-industry innovation literature stakeholders who can be the sources of innovation, for example, lead users, experts, suppliers and researchers, are discussed (Carmona-Lavado *et al.* 2023). Some studies focus on the intermediate roles that help bridge gaps between the different industries (Gassmann *et al.* 2011), but how the roles of various actors interplay in cross-industry innovation is less explored. Thus, how interdependencies and interaction among the actors affect the innovation process and its outcomes must be

taken into consideration, as no actor undertakes its role in isolation but through its connections to others. Therefore, the next section presents the Industrial Network Approach.

Industrial network approach (INA)

The Industrial Network Approach (INA) (c.f. Håkansson and Snehota 1995; Håkansson *et al.* 2009) is used as the theoretical lens to study the development of a collaborative innovation network focusing on the interdependencies, interaction and relationships of various participants within the network. In a cross-industry innovation, the innovation network will accordingly “stretch” across various industries. The INA approach views innovation as the result of interactions between actors in a network, and a new solution, which is a result of interaction, is an innovation only if it remains through developing, producing and using settings (Håkansson *et al.* 2009, Bygballe *et al.* 2015). The phenomenon of interaction is complex and dynamic in nature (Håkansson and Snehota 1995). The output of one interaction becomes an input to the next, and this is interpreted differently by the parties involved (Håkansson *et al.* 2009). Moreover, interaction can be more or less intense, and over time, interaction between parties can change in nature (*ibid.*). These interactions leave traces that impact the people and resources involved. Interaction poses a major means through which organizations systematically combine their resources and activities. Consequently, “organizational interfaces” come into existence, with various features of interaction patterns and levels of involvement (Araujo *et al.* 1999). Hence, the characteristics of interaction and organizational interfaces capture how actors, their resources and activities, relate in an innovation network.

The ARA model enables the conceptualizing and analyzing of interaction in the three network layers of actors, resources and activities (ARA) (Håkansson and Snehota 1995). These layers exist within organizations, in relationships between two parties and in larger structures where various relationships are interconnected and networks are formed (c.f. Håkansson and Snehota 1995). The network is in constant motion in which actors co-evolve, resources move along in a particular direction, and activities become more accurate in one or more parts. Therefore, there is no fixed point for the interactive elements that provide major change and stability and hence, interaction is referred to as a dynamic, multi-dimensional process (Håkansson *et al.* 2009). Conceptually, in the ARA model, the actor layer refers to the business actors, driven by various motives,

who influence and are influenced by other actors through *actor bonds* as part of business relationships. The way that actors relate to each other is dependent on recognitions and interpretations, with three interrelated variables involved in acting: *perception* (the cognitive representation of the context); *behaviors* (the actual acts); and *results* (intended and expected) (Håkansson *et al.* 2009). The resource layer comprises both *tangible resources* (e.g., products) and *intangible resources* (e.g., knowledge) that, through resource combining, become embedded or transformed in *resource ties* as part of business relationships. The activity layer describes the actions performed by the actors forming *activity links* and how they coordinate independently or collaboratively to create value in the business relationship (Håkansson and Snehota 1995). Håkansson *et al.* (2009) identify three types of activity interdependencies, which can also co-exist. Firstly, *serial interdependence*, refers to “a specific activity that cannot be performed until another one has been completed” (Håkansson *et al.* 2009, p. 105). Secondly, *dyadic interdependence* refers to “the output from one activity serves as input for the other activity and vice versa” (Håkansson *et al.* 2009, p. 106). Thirdly, *joint interdependence* occurs when the performance of one activity is dependent on another, because both of them are related to a third activity” (Håkansson *et al.* 2009, p. 107). Based on the ARA model, a conceptual framework for scrutinizing interaction in a cross-industry innovation network is presented in Figure 1. Given the content and nature of networks, resource mobilization, coordination of activities and sometimes advancement of knowledge depending on the interconnections of the involved actors, cross-industry innovation processes are dynamic. What happens in one relationship is also contingent on other relationships, and innovation influences actors, resources, and activities sequentially but also across the larger network (Bygballe and Ingemansson 2014).

Research design

The study employed a qualitative research approach as it could “raise new questions that will reveal deeper insights into management, organizations and society that are crucial to understanding and potentially shaping our world” (Bansal and Corley 2011, p. 235). The research approach was grounded in systematic combining guided by an abductive logic (Dubois and Gadde 2002b). Accordingly, the research process was characterized by the intertwined and iterative nature of different research activities, such as, interpreting

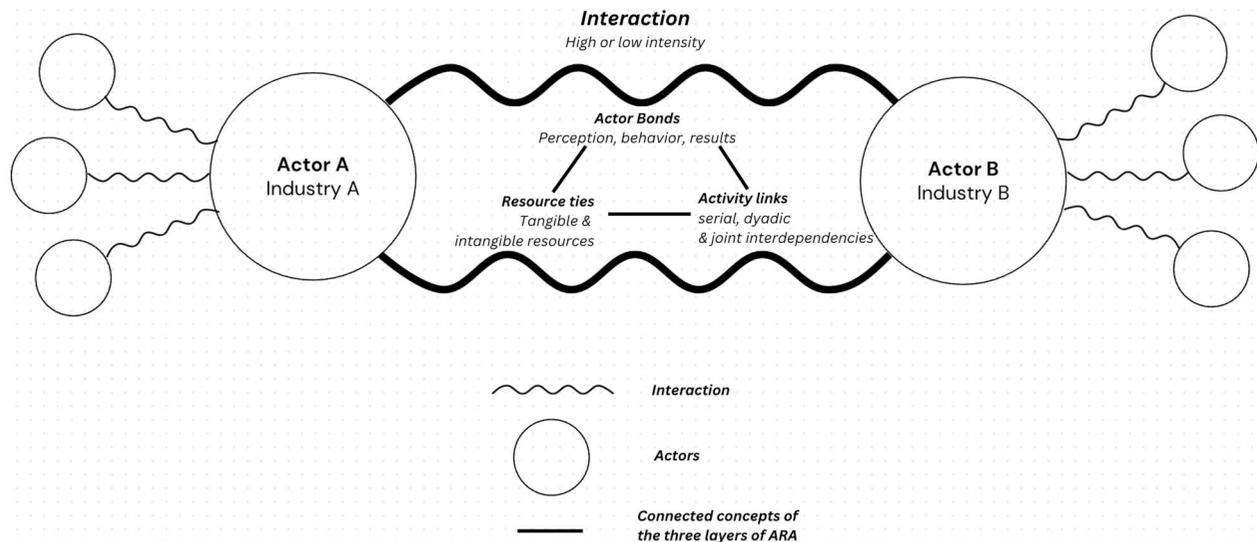


Figure 1. Conceptual framework of interaction in cross-industry innovation (CII).

empirical observations, engaging with theoretical literature, and allowing empirical findings and theory to inform each other continuously (ibid). Initially, the purpose of the research was to explore the inter-organizational innovation process in a construction setting by conducting a single case study. The starting point of the empirical investigation was the collaboration of two actors: the contractor, CC, from the construction industry, and the truck manufacturer (TM) from the automotive industry, in an innovation process. As the actors come from different industries, the innovation process was characterized as cross-industry innovation. The actors co-developed an innovative digital application, named the “Efficient Load Out” application. This application emerged as part of a large urban infrastructure project in Sweden aimed at addressing complex sustainability challenges related to transportation and logistics. Successively, in the research process data collection expanded to include other actors, such as subcontractors, due to their involvement in the innovation process. Hence, the empirical investigation came to cover an innovation network across industries.

Case study research is widely recognized as a well-suited approach in efforts to describe and understand processes in a network (Andersen *et al.* 2018). In accordance with the research phenomenon of inter-organizational innovation, literature on construction innovation and collaborative innovation was covered. Drawing on the literature, an interview guide was developed with the following themes: features of the innovation, the innovation process, characteristics of the collaboration and the relationship, how the innovation is used as of today (at the time of interview),

value and usefulness of the innovation and, challenges in relation to the innovation process and its outcomes. The empirical data was collected through sixteen semi-structured interviews (see Table 1), all of which were recorded and transcribed. Participants were purposively selected for their involvement in the innovation process, included representatives of the main construction contractor (CC), the truck group conglomerate (TGC) with its separate companies the truck manufacturer (TM), the truck construction equipment company (TCE) and the truck technology developer company (TT), and two subcontractors: transport & logistics subcontractor (SC1) and transport & logistics service provider (SC2). The case study gave opportunities of collecting data over different time phases, as well as to capture the changes that took place in the innovation process in its different phases (see Figure 3). The data collection retrospectively identified and covered four phases of the innovation process: initiation (year 2020), development (year 2020), pilot (year 2022), and scale-up (year 2023) (see Table 2). Interview data for the initiation and development phases were collected retrospectively in 2021, whereas follow-up interviews relating to the pilot and scale-up phases were conducted in 2023. In addition, data was collected by observing a meeting (in 2021) when the involved parties discussed how the Efficient Load Out application could be developed further.

As the research progressed and in line with what the case illustrated empirically, the research phenomenon was adjusted to cover how a cross-industry innovation network evolves, following a systematic combining of theory and the empirical world (Dubois and Gadde, 2002). As to scrutinize this phenomenon,

Table 1. Overview of Interviews.

	Firms	Title	Duration	Time period of data collection
1	CC- Construction contractor	Project Development Manager	1h 30m	2021
2	TCE - Truck construction equipment company	Road Business Development Manager	1h 10 m	2021
3	TCE - Truck construction equipment company	Program Leader Service Solutions Emerging Technologies	1h 20 m	2021
4	TM-Truck manufacturer	Services Strategy Manager	1h	2021
5	TM-Truck manufacturer	Portfolio Director	1h	2021
6	TM-Truck manufacturer	Business development in new services	1h	2021
7	CC- Construction contractor	Nordic Business Development Engineer	1h	2021
8	TT-Truck technology developer company	Service innovation manager	1h	2021
9	CC- Construction contractor	Production manager	1h	2021
10	CC- Construction contractor	Block Manager Excavation and Foundation	1h	2021
11	SC2 - Sub contractor - Transport & logistics service provider	Transport Supervisor	1h	2021
12	SC1-Sub contractor- Transport & logistics sub-contractor	Manager Future Development Transport	1h	2021
13	CC- Construction contractor	Infrastructure Manager – Design	1h	2023
14	CC- Construction contractor	Infrastructure Manager – Design	30m	2024
15	CC- Construction contractor	Head of Research and Innovation	1h	2023
16	TCE - Truck construction equipment company	Product manager	1h 10 m	2023

Table 2. Key resource ties, activity links and actor bonds in the innovation network.

Actors involved	Resource ties -Tangible/Intangible	Activity links - Serial/Dyadic/Joint interdependences	Actor Bonds - Perception/ Behaviour/Result
Initiation Phase			
TGC-Truck group conglomerate	Innovation knowledge IT systems, logistic solutions, and transportation knowledge (intangible)	Dyadic interdependencies TGC - CC	To reduce CO2 emissions, to improve efficiency of transports and for business development
CC – construction contractor	Construction knowledge, project-based competences (intangible)		To reduce CO2 emissions, to co-creating digital application to meet digital requirements in the construction project
Development phase			
TGC-Truck group conglomerate	Construction trucks, construction equipment & technology development (tangible)	Serial interdependencies within TGC Dyadic interdependencies TGC - CC	Digital solution development & testing
CC – construction contractor	Construction project site (tangible) and onsite logistics knowledge (intangible)		To meet the digital requirement for project
SC- Sub contractor	Logistics and transport equipment (tangible)		Optimize transport
Pilot Phase			
TCE- Truck construction equipment company	Digital solution application	Joint interdependencies TCE – SC1 Dyadic interdependencies TCE and SC1- CC	Digital solution implementation
SC- Sub contractor	Transport & logistics knowledge and feedback on ELO		Access to digital solution and usage
CC – construction contractor	Project site coordination and feedback on ELO		Digital solution usage
Scale up Phase			
TCE (ELO)	Ownership of digital application	–	Expanding business beyond the project
CC – construction contractor	–		Digital application usage as a service
SC1 and SC2- Sub contractors	–		Digital application usage as a service

the Industrial Network Approach was applied as the theoretical lens. In accordance with the research process going back and forth from theory and the empirical work to cover the phenomenon, a conceptual framework of interaction in cross-industry innovation (see Figure 1) was developed and data analysis was performed. The analysis begins during the data

collection and typically uses codes, themes or categories to see patterns in the qualitative data, that helps in establishing meaning to the level of informants' description" (Magnani and Gioia 2023). The preliminary data analysis was performed by applying the ARA model from the Industrial Network Approach (Håkansson and Snehota 1995) as coding tool. The

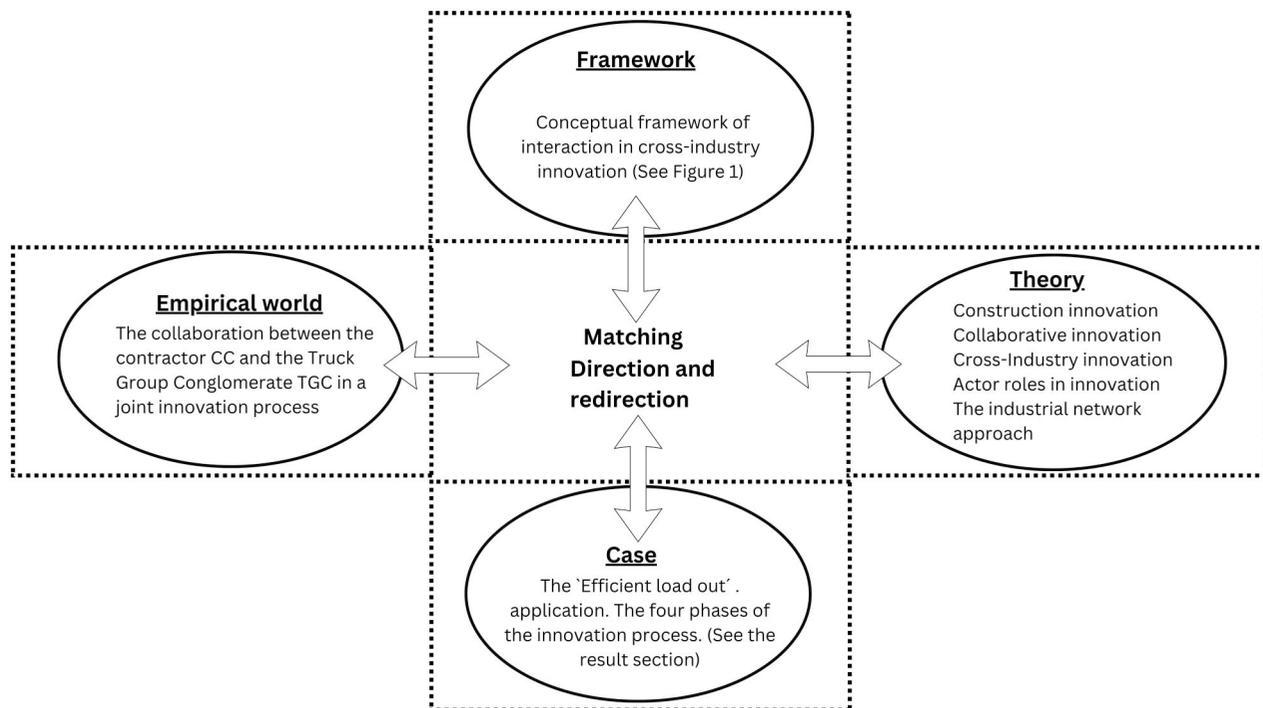


Figure 2. Research process – Systematic combining (Adapted from Dubois and Gadde 2002b).

coding was done using NVivo software 15, which allowed interview transcripts' data to be categorized into more specific network layers of resource ties, activity links and actor bonds in the four phases of the innovation process (see Table 2 for content of resource ties, activity links and actor bonds). In line with the conceptual framework (see Figure 1), data was analyzed further in detail to see the patterns based on concepts of interaction in the three layers. As an example, in the activity dimension, the inter-organizational activity interdependencies, i.e., the way the two industries coordinated their off-site activities (digital application development, which follows serial interdependency) and onsite activities (digital application testing on construction site, which follows dyadic interdependency) were analyzed. The above-mentioned analysis of data formed the basis for further literature exploration on cross-industry innovation, and actor roles in the innovation process. Following Dubois and Gadde, p. (2002b, p. 556), the current study embraced the principle of "the ultimate matching of theory and reality", confronted with the evolving conceptual theoretical framework (Figure 1) and case formation emphasizing the dynamics in the interaction between cross-industrial actors. As a result of continuous matching, direction, and redirection, our research focus shifted from merely exploring the inter-organizational innovation process (initial point), to a refined research question: How does a cross-industry collaborative innovation network evolve in a

construction setting? The single case serves as an illustration to scrutinize the dynamics of interaction and interdependency in the analysis of the phenomenon of a collaborative cross-industry innovation from a process viewpoint (Siggelkow 2007). Accordingly, the empirical data revealed four phases of innovation, based on the complexity and progression described by participants and consequently, the analysis is structured in accordance with these phases. These phases encompassed the progression of the innovation process from initiation to scale up, including key challenges, enablers, interaction and interdependencies, and the role of various actors in the collaboration. This analysis revealed critical points of interaction within the innovation process and provided evidence for illustrating the importance of network structures in fostering innovation.

The conceptual framework (Figure 1 in the theoretical background section) and the case description presenting the digital application and the phases of the innovation process (in the results section) are thus outcomes of the research process in line with the systematic combining approach. Additionally, the discussion section in the current paper presents the descriptions, insights and explanations generated based on the conceptual framework following "the theory building in the interpretive paradigm" (Magnani and Gioia 2023, p. 588). The systematic combining approach with its key elements and outcomes in terms of the conceptual framework and the case is illustrated in Figure 2 below.

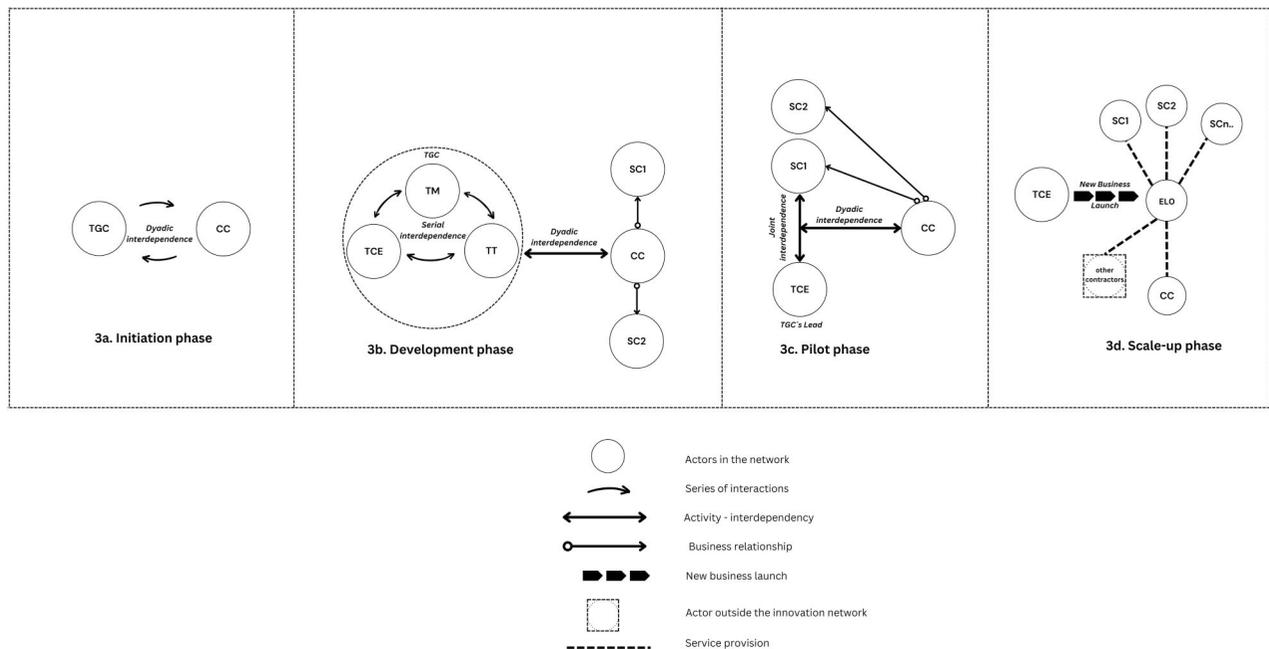


Figure 3. Innovation network development across four phases.

In the writing process of the paper, a responsible application of the generative AI tool Chat GPT-4 was used for language improvement.

Results

Firstly, the features of the “Efficient Load Out” application, the reasons for initiating an innovation process, and the use of the application are described. Secondly, by applying the conceptual framework (see Figure 1) the analysis identifies key features of resource ties, activity links and actor bonds in the four phases of the innovation process (see Figure 3 and Table 2).

The case: the Efficient Load Out application

A collaborative innovation process was initiated by two main actors: the main construction contractor CC and the truck manufacturer TM who belonged to construction and automotive industries respectively, with the aim to develop a digital application. The actors had a history of collaborating on several sustainability and efficiency initiatives and had developed a strong, trust-based relationship over time. Based on this longer-term continuous interaction, the two actors formulated a joint innovation goal: to reduce CO₂ emissions for transport and solve logistics challenges for a construction infrastructure project. Consequently, the idea of developing a digital application, the “Efficient Load Out,” emerged. Due to the expected features of the digital application, early in the initiation of the innovation

process, the truck construction equipment company TCE and the truck technology developer company TT, both of which, along with truck manufacturer TM, belong to truck group conglomerate (TGC), got involved. The site of a large transportation infrastructure project in a large Swedish city was used to develop and test the application. The construction project consisted of a train station, a train tunnel and railway, all underground, as well as a bridge over a motorway. The public client for the infrastructure project had a unique requirement: demanding digital receipts for truck loading and unloading delivery work. This opened an opportunity for the “Efficient Load Out” application to not only integrate the requirements from the public client to streamline the loading and removal of excavated material, but also to use the infrastructure project site as a platform to test the new digital application. The developed application, the “Efficient Load Out,” enabled the maximum utilization of load capacity on every transport, all in all, being able to reduce the total number of transports with materials leaving the site.

By using the Efficient Load Out application the truck drivers and excavators could monitor their load using the vehicle digital scale that continuously updated the information into the digital application. After loading was completed, the personnel responsible for delivery updated the information digitally as to what material was loaded, its load weight and where the load was to be transported. According to the construction industry actors, the digital application provided great benefits for the work on site, i.e., less administration, increased

productivity, reduced environmental impact, and improved safety. The benefits for the automotive industry actors included the possibility to develop a new service that later could be offered to other construction sites and companies. The data that had been collected by the testing and use of the “Efficient Load Out” application in the construction infrastructure project was crucial for developing the new service. Over time the digital application improved with better updates, offering not only the necessary scope, but also exceeding expectations to become a complete solution for managing mass excavation projects. The automotive industry actors were able to scale the solution into a new business by launching a start-up company named ELO (for the purpose of this study), as a service provider. Although the solution provided great benefits for CC in the infrastructure project, the challenge was to implement the use of the innovation in other projects, in other words, scaling up the use of the “Efficient Load Out” application. The ownership of the application as well as the data collected through the application was in the hands of the automotive industry actors, which made scaling-up challenging for the construction industry actors.

As the innovation process progressed several actors got involved besides the main contractor CC and the truck manufacturer TM. These included the truck construction equipment company TCE and the truck technology developer company TT, both of which, along with truck manufacturer TM, belong to truck group conglomerate (TGC). Additionally, two subcontractors participated in the process: the transport & logistics subcontractor SC1 and the transport & logistics service provider SC2. The involvement of these actors and the different phases of the innovation process are presented in the following section.

Initiation phase

The initial phase consisted of the idea and concept generation for developing the digital application, and only a small team of people from the two actors, the truck manufacturer (TM) and the construction contractor (CC), were involved. Although TM and CC had a joint goal and initiation of the innovation collaboration, TM also had a strategy to broaden their servitization and advance their digital application offering in the construction industry, aligning with their business development goals. The actors initiated the collaboration based on an understanding of their respective core competencies and specializations required for the innovation. The resource tie that was formed between

CC and TGC combined knowledge about construction, truck technology, IT systems, logistic solutions, and transportation knowledge, which are categorized as intangible resources (see Table 2). The actors were aware of that the combining of these diverse resources was crucial for developing the digital application. *“The [TGC] and their teams have helped us a lot, but they [TGC] would not have been able to provide a solution if we hadn’t communicated our requirements to them openly”* - Project development manager CC

Accordingly, these interactive activities of communication are featured by a dyadic interdependency between the actors with high intensity interaction. As a result, a business relationship was established, creating a base for a collaborative innovation network. Although the actors had a history of a relationship, it was not common that the truck manufacturer and the construction contractor worked in a joint innovation project. Also, the truck group conglomerate TGC usually work with transport providers as customers, but they TGC emphasized the necessity of gaining insights from the whole construction industry context to be able to offer services that suit the needs of the construction industry.

“We [TGC] have started to go to the main customer such as construction companies and started to learn about their onsite work on a daily basis” – Product owner TCE. Additionally, a project manager from CC acknowledges the above statement and states:

This collaboration is that they [TGC] have learned how their customers act [for example, transport and logistics providers] and have seen our workplaces as a conglomeration of excavators. They have learned a lot of how our (construction) business works in depth – Project development manager CC

Overall, the trust among the actors was perceived as mutually beneficial and strengthened the actor bond characterized by the perceptions and expectations of the actors, which paved the way for developing the digital application. The product owner from TCE stated, *“the start of everything that we do in the business now comes from the ‘Efficient Load Out’ and what we have learned during the journey together with construction contractors.”*

The features of interaction in the initiation phase of the innovation process are summarized in Table 2 and illustrated in Figure 3a.

Development phase

The development phase consisted of activities performed by the actors when combining technical and

physical resources to develop and test the digital application. TGC contributed with their technical expertise(intangible) in developing the digital application. Conversely, CC's contribution was by providing a large construction site(tangible) for the development and testing of the digital application, which was regarded as a critical resource in the collaboration. This reciprocal resource dependency between TGC and CC resulted in a dyadic interdependency during this phase.

The actors within TGC performed activities that featured serial interdependence amongst them, i.e., TCE's role was contingent upon the completion of TT's development of the technical part of digital application, TM served as a central actor within the TGC organization, providing strategic direction for the workflow to manage the innovation project. During this phase, CC played a central role in coordinating the innovation process at the construction site, by integrating various actors when facilitating subcontractors' involvement. CC is indicated as a central actor, 'the star', who performed innovation coordination by choosing the relevant actors and involving them in the innovation network. The interviewees acknowledge this (central actor) role when a production manager from CC states:

The subcontractor [SC1] came along to see what was possible in technology development with regards to logistics and hence we [CC] chose them [SC1] due to their interest in digitization and technology development.

Driven by the serial interdependence within TGC (intra-organization collaboration) and dyadic interdependence between TGC and CC (inter-organization collaboration), the development phase overall had the highest intensity of interactions in terms of resource ties in relation to the actor's collaborative behaviors and in combining the tangible and intangible resources. The mutual understanding led the actors to have trust and depend on each other to achieve the goal of developing an efficient solution. The design manager from CC recognized the dyadic interdependency and stated:

But we looked at other industries, what they have done for a long period of time and see if we can apply it to our industry as well. Because you don't have to invent the wheel every time.

Additionally, "It's very important that everyone earns their money, so someone does not have to take all the costs by themselves. To have everyone happy and get a win-win situation." further adds the CC perspective on this collaboration.

The features of interaction in the development phase of the innovation process are summarized in Table 2 and illustrated in Figure 3b.

Pilot phase

The pilot phase consisted of activities that led to the extension of the innovation network. There were several actors involved in this phase. Firstly, TCE led the testing of the application, due to their extensive onsite experience with construction equipment and knowledge about innovation testing. Secondly, the subcontractor SC1, who had a business agreement with CC, managed logistics and transportation on site, which involved extensive administration. Thirdly, the subcontractor SC2, who also had a business agreement with CC, provided for the transport of excavated masses, on site and to the landfill sites. Lastly, site representatives from CC were actively involved in this phase when coordinating on-site activities.

During the testing of the digital application, the TCE recognized that not only gaining access to a physical construction project site was crucial for them but also interacting with SC1 was helpful with regards to understanding construction transport and logistics handling on site on a day-to-day basis. By being involved in the innovation process, SC1 gained access to the digital application that improved their processes in reducing fuel consumption, optimizing the number of trips and load weight which reduced the wear and tear of the truck components. While CC received benefits from the digital application in line with their initial goal of reducing CO₂ emissions in the project, they also benefited from solving problems on the construction site, that were not initially anticipated. For example, due to changing the manual processes to obtaining data digitally, the digital application benefited CC in achieving efficient onsite administration along with improved safety. Furthermore, it improved onsite logistics by lowering the number of transports which reduced vehicle traffic and also environmental impact. Therefore, these additional advantages contributed to the productivity, described by the managers from TT and TM:

However, some of this productivity perhaps wasn't given too much emphasis initially but that was one of these ripple effects that produced administrative efficiency and productivity.

SC1 was initially in a business relationship with CC for the infrastructure project. Additionally, SC1 got involved in the testing of the digital application along with TCE during the pilot phase. Their involvement led

to the extension of the network by obtaining relationships with new actors (TCE) and the access to the digital application. Both SC1 and TCE depended on each other's resources, i.e., transport and logistics provision using excavators and "The Efficient Load Out" application respectively, to continuously optimize and use the innovative digital application to deliver the requirements of the project. The activities of TCE and SC1 featured joint interdependencies as pilot testing on the site were contingent on excavation (SC1) and monitoring and fine-tuning the application (TCE). This interdependency between TCE and SC1 was facilitated by CC and is acknowledged by the design manager from CC:

I think in the beginning we [CC] got to borrow some machinery from the truck construction equipment (TCE) to see if it worked. And then, SC1 equipped all their excavators with this new service [Efficient load out application]

TCE, in a way, became the leading actor in this phase because they had the knowledge of testing and implementing the innovation on site. Overall, TCE was taking the role of a "pilot lead," while CC was a contributor in this phase providing continuous feedback on the digital application. However, the relationship dynamics between the main cross-industry actors, TGC and CC, still maintained a dyadic interdependency but with less intense interaction. The earlier reciprocal interdependence between the main actors shifted to a one-sided dependency that made the business interaction weak for the dependent partner, i.e., the construction contractor.

The features of interaction in the pilot phase of the innovation process are summarized in [Table 2](#) and illustrated in [Figure 3c](#).

Scale up phase

This phase consisted of scaling the innovative digital application. With the successful innovation development, TCE within the TGC company launched a new business in the form of a start-up company referred to as the "ELO"(in this study). TCE entered a new market by scaling the innovation and selling it as a service to other construction contractors and sub contractors. CC benefited by gaining from increased productivity on the site leading to greater efficiency, in the construction project. However, they realized that scaling the innovation was hard as each construction project is run by its own premises and a decentralized discretion over how to spend the budget. As stated by construction technology manager from CC:

The project manager has the decision-making capacity on the budget to use the 'Efficient Load Out' application in the project or not. Nobody in the higher level of the construction company tells the project manager that they need to use the digital application, therefore it's a decision made at the project level.

Furthermore, TCE owned the application as well as the project data (in relation to logistics and transport). This situation posed a challenge for the construction contractor (CC), as the digital application was not exclusive to their organization, and they could only help develop it and use it. This raised the question of how much data they had to supply as input to the application to extract the necessary requirements. In response to this the construction technology manager (CC) stated:

We've had this contract that we could discuss the innovation development between each other, but not exclusivity of the solution.

In the scale up phase, the innovation development project was completed, and there was a low-intensity interaction between TGC and CC due to weak resource ties and activity links. While the construction contractor still had to interact with ELO (the new service business) to continue to access the digital application, but now it was with a subscription plan. Additionally, the key individuals who initiated the innovation process within CC had left the organization which hindered long-term exploitation of the innovation process for CC.

The features of interaction in the scale-up phase of the innovation process are summarized in [Table 2](#) and illustrated in [Figure 3d](#).

[Table 2](#) below presents a summary of the analysis of key resource ties, activity links and actor bonds in each phase of the innovation process.

[Figure 3](#) below illustrates how the cross-industry collaborative innovation network evolves in the four different innovation phases.

The analysis of the various phases of the cross-industry innovation process highlights the complexity in the collaborative innovation network in terms of interactions and interdependencies. Hence, the use of the selected framework has supported a nuanced view of the interaction and dynamics taking place.

Discussion

The analysis of the various phases of the cross-industry innovation process revealed the complexity of interdependencies that continually emerged and transformed due to interaction in the innovation network. Thus, the dynamics in the innovation process, within

Table 3. Key dynamics due to network interdependencies in the innovation process.

	Initiation	Development	Pilot	Scale up
<i>Interaction</i> CC - TGC	High intensity interaction due to exploring actor bonds and mutual understanding across industries	High intensity interaction due to strong resources ties when combining resources across industries	Less intense interaction due to activity links to coordinate activities across industries	Low intensity interaction due to weak actor bonds, resource ties and activity links across industries
<i>Organisational interface</i> CC - TGC	Interactive interface	Translation interface Specified interface	Translation interface Specified interface	Standardized interface
<i>Actor roles</i>	CC: Initiator TM: Initiator	CC: Champion TGC: Main developer	CC: Contributor TGC: Pilot lead	CC: User TGC (via start-up ELO): Solution provider

the innovation network across industries, came into existence and were manifested through these interdependencies. The key dynamics of the relationship between the contractor CC and the truck group conglomerate TGC, that evolved due to interdependencies, are discussed next in terms of interaction, organizational interfaces and actor roles (see Table 3).

The dynamics of interaction

As the analysis showed, the dynamics of interaction played a pivotal role in the innovation process. The resource ties, activity links, and actor bonds that were formed in interaction enabled the innovation, and the nature and content of such interaction also changed during the innovation process. Accordingly, while interacting among actors, combining of resources and coordinating activities took place in all phases, the interaction between the contractor CC and the truck group conglomerate TGC changed from high intensity (initiation and development phases), less intensity (pilot phase) to low intensity (scale up phase). In terms of key features of the interaction, there was a shift of dynamics from a strong focus on exploring actor bonds (initiation phase), strong resource ties (development phase) and activity links (pilot phase), to weak actor bonds, resource ties and activity links due to low interaction intensity (scale up phase). This constituted the dynamic evolving nature of the innovation process (see Table 3).

As such, the “context dependency” (Harty 2008, Bygballe and Ingemansson 2014) in relation to cross-industry innovation is a matter of network interdependencies: the connectedness among various heterogeneous resources that industry actors possess, the respective activities they can perform and their ability to interact, rather than industry specifics in general. Furthermore, what happens in the focal relationship between the main contractor CC and the truck group conglomerate TGC was contingent on other relationships in the innovation network, for example, the

contractor’s relationship with the public client, and the relationships with subcontractors, as the relationships became connected via the interaction in the innovation process. Consequently, the innovation network evolved due to how interactions interplayed. The nature of the interdependencies and parties’ abilities to interact in the network could either strengthen or weaken their collaboration. Ultimately, how the focal relationship between the contractor and the truck group conglomerate was maintained over time and in relation to interconnected relationships determined the success of the cross-industry innovation process.

Also, the interaction in the innovation process was affected by the experiences the actors had from previous interaction episodes and expectations on future interactions, for example, regarding potential customers buying the digital application. As such, the innovation process for the Efficient Load Out application was “embedded” in a larger setting in space and time, due to network interdependencies (Havenvid 2019; Håkansson and Snehota 1995). This supports prior research stating that the very same innovation is implemented and constituted very differently in different contexts (Harty 2008, Bygballe and Ingemansson 2014). Accordingly, for the construction industry, the innovation was incremental based on Slaughter’s (1998, 2000) definition as transport and logistics was improved but had little impact on the construction components or connections and relations to its core infrastructure project. In contrast, from the point of view of the automotive industry the innovation offered a major increase of state of knowledge, created connections to components, systems and other actors. This is in line with the relative boundedness of innovation (Harty 2008).

The dynamics of organizational interfaces

The “Efficient Load Out” was a coupled cross-industry innovation as parties from different industries collaborated to develop a new solution (Gassmann *et al.*

2011, Carmona-Lavado *et al.* 2023). The findings showed that the organizational interface between the contractor CC and the truck group conglomerate TGC changed in nature due to various needs of collaboration among the parties. In line with research of organizational interfaces between parties who jointly develop a product, service or solution (Araujo *et al.* 1999, 2016, Andersen and Gadde 2019), including the construction industry (Eriksson *et al.* 2021), initiation of the innovation process took place in an open-ended dialogue taking into account the total set of capabilities and the contexts of the two parties, identified as a so called “interactive interface.” It was crucial that both parties had the “interactive capacity” (Araujo *et al.* 2016), that is, both the construction contractor and the truck group conglomerate had to devote the essential amount of time and other resources to interaction, as to achieve the necessary mutual understanding. The skills and knowledge on how to interact with each other, so called “interactive capability” (*ibid.*), had developed over time for both parties due to previous interactions. However, during the innovation process, the initial interactive interface transformed. Contingent on this, the interaction evolved with characteristics of a “translation interface” in the development and pilot phase with a focus on translating the needs of the actors in the construction project to be able to design and produce a solution enabled by the truck group conglomerate TCG in the automotive industry. Due to a continuous “looping” between the development and pilot phases as the digital application was progressively designed with more features, the development and pilot phases also had elements of a so called “specified interface,” when detailed instructions guided the interaction. Finally, in the scale up phase, the organizational interface between the construction contractor CC and the truck group conglomerate TCG transformed into a “standardized interface” with a typical arm’s length relationship and very little involvement between the parties. Apparently, a process for joint development of an innovation might contain various organizational interfaces between two parties in interaction episodes over time, which is a more nuanced understanding than previous research which states that joint development mainly takes place in interactive interfaces.

The dynamics of actor roles

The changing interaction in the various phases of the innovation process due to network interdependencies had implications for the actors’ roles. Accordingly, the

functions carried out by the actors in the innovation process were contingent on how they related to each other. Thereby, these findings provide new insights on actor roles in cross-industry innovation, besides existing knowledge on who can be the sources of innovation (Carmona-Lavado *et al.* 2023) or intermediate roles that are bridging the gap between the different industries (Gassmann *et al.* 2011). Across the innovation process, the roles have been named based on their function (see Table 3).

The contractor CC and the truck manufacturer TM initiated the innovation process jointly in its very early phase, but soon the other actors of the truck group conglomerate TCG got involved. The role of the truck group conglomerate TCG followed a regular pattern in innovation processes, i.e., moving from an initiator role to main developer, then becoming a pilot lead, to becoming a solution provider in the final phase. This was not surprising, as manufacturing industries often adopt a strategic, systematic approach when managing innovation processes. In the initiation phase, the construction contractor CC adopted idea generating behavior by conducting informal relations (Slaughter, 2000) outside of the construction project to initiate the innovation process. During the development phase, the contractor took on a champion role (Sergeeva and Zanello 2018), due to the need of coordinating construction project activities, resources and actors on site with the development carried out by the truck group conglomerate. This confirms the need of an actor who coordinates resources and activities for the preparation of innovation implementation (Slaughter 2000), in this case taking place at the construction site in the infrastructure project. Later, in the pilot phase the role of the construction contractor CC became a contributor of feedback and during the scale up phase, the contractor’s role became a regular user of the digital application.

While the shifting roles of actors throughout an innovation process is a common phenomenon, it presents unique challenges for the construction industry actors, particularly when collaborating with a mature, innovation-driven partner (the truck group conglomerate TCG) who is used to working in a non-project-based setting with expectations on more long-term outcomes of an innovation. The cross-industry collaboration brought benefits to both the actors, which supports other research on the benefits of inter-organizational collaboration for innovation in general (Satheesh *et al.* 2024), and digitalization specifically (Carmona-Lavado *et al.* 2023). However, for the contractor, the main benefits were short term, related

to the project context and fulfilling the project requirements, which confirms prior research pointing to that in terms of innovation, contractors often focus on “temporary solutions” to solve project related problems (Eriksson and Leiringer 2015, Havensid *et al.* 2019, Larsson *et al.* 2022,). Beyond the specific project context, the contractor became a regular customer paying for using the solution but not being able to exploit a business opportunity in relation to the innovation. However, the contractor gained a lot of knowledge concerning interacting in innovation networks, in particular with regard to collaboration with non-project-based organizations like the truck group conglomerate, a useful lesson learned for future innovation projects.

The truck group conglomerate’s TCG more long-term strategy to expand their business into the construction sector with digital services, a relatively new venue, was a unique scenario. Through every phase of the innovation process, the truck group conglomerate gained valuable knowledge about construction, ultimately achieving their objectives of the innovation collaboration of business expansion with a new type of solution targeting the construction industry. Not only did they establish themselves in a new market, but they also gained a competitive edge by offering efficient and sustainable solutions tailored to the construction industry to other construction actors. Hence, the roles of the actors related to their perceptions, behavior and expected results and outcomes when engaging in the innovation process. This adds to the understanding of the relative boundedness of innovation (Harty 2008); not only did the innovation play out differently for the actors due to context, but the functions and parts played by the actors in the innovation process were also related to contextual factors.

Theoretical implications

Summing up, the paper contributes to construction innovation research by scrutinizing the dynamic changes over time in an innovation process, which has been called for by previous studies (Harty 2008, Bygballe and Ingemansson 2014, Bygballe *et al.* 2015). The study included the long-term use of innovation, which is seldom the case in innovation studies, which tends to cover a single point in time (or short-term use) of the innovation. The findings showed that key dynamics consisted of changes in interaction, organizational interfaces and actor roles in the innovation process, which evolved due to interdependencies in the innovation network. Accordingly, the specific characteristics of

interaction, organizational interfaces and actor roles form the context of innovation, which adds to the understanding of the relative boundedness of innovation (Harty, 2008). More specifically, this contributes to cross-industry innovation research, of which studies involving the construction industry are scant (Carmado-Lavado *et al.* 2023), by providing a more nuanced understanding of how various industry contexts, of where the construction industry is one, interplay and affect the innovation process. Moreover, analysis of the dynamic aspects of the innovation process by applying the Industrial Network Approach (e.g., Håkansson *et al.* 2009), showed how the actor roles were formed due to interaction among parties, which advances the existing body of knowledge on construction companies’ roles in construction innovation (Slaughter 2000). Furthermore, the results add to the concept of “organizational interface” introduced by Araujo *et al.* (1999) by identifying that an interactive interface, which is the case of joint development between two parties, is not heterogenous over the innovation process, but can have episodes of interaction characterized by translation interfaces and specified interfaces.

Conclusions

The purpose of this research was to explore how a cross-industry innovation network evolved in a construction setting. As the conducted case study was distinguished by actors involved in innovation from the construction industry and the automotive industry, the research covered cross-industry innovation. By drawing on the industrial network approach (INA), this research scrutinized complex network interdependencies with insights on dynamic changes in terms of continuously changing interaction, organizational interfaces and actor roles across initial, development, pilot, and scale up phases of the innovation process. The innovation network that formed through collaboration highlights both the opportunities and challenges in cross-industry innovation processes and gives more nuanced insights in terms of how contextual factors affect innovation, that is, the context dependency of innovation.

In conclusion, whereas characteristics on the industry level, i.e., for the construction industry being a project-based industry often with a problem-solving mindset for innovation and for the automotive industry copying with innovation as a strategic approach for long term business opportunities, do have some implications in terms of explanatory factors for a cross-industry innovation process’s features and its outcomes, it also provide an extreme simplification.

Instead, acknowledging the specific characteristics of the actors' interaction and interdependencies among them, their activities and resources, stretching across the industries in the innovation network over time, provided a deeper understanding of prerequisites and outcomes in cross-industry innovation. The success of the innovation process is contingent on the abilities of organizing the innovation process to cope with these interdependencies among the collaborating actors in the network. The actors' previous experiences and future expectations on the innovation process affect altogether, this explicates and contextualizes how an innovation network evolves in cross-industry innovation. Accordingly, context dependency in cross-industry innovation is dynamic due to network interdependencies as the innovation process is embedded in time and space. This provides more nuanced insights into the relative boundedness of innovation; that is, the context dependency of innovation, besides industry features in general.

This research offers practical insights for construction contractors by clarifying the roles and associated competences required to advance an innovation process. Additionally, it provides construction contractors with the necessary learnings to proactively collaborate in the future and offers ways to bring in digital innovation knowledge from other industries into the construction sector. Contractors must acknowledge the interactive aspects of collaboration, including how network interdependencies come into existence and how features of relationships affect the innovation process. In particular, in relation to digital innovation, the research shows that data is a vital resource that needs to be managed and can provide major benefits across projects and as part of future business. This requires a mindset among managers going from digital technology as a problem-solving entity, to digital technology as a business development opportunity.

The findings of this research are limited to a single case study within the Swedish context. Additionally, the study is constrained by its focus on cross-industry innovation between the construction industry and the automotive industry. Another limitation lies in the study's focus on digital innovation rather than general innovation. The results reveal a pattern in how roles evolve across different innovation phases and their potential connection to the change in interaction and interdependencies. This presents an opportunity for future research to explore the relations between roles and interdependencies and their impact on innovation progress. Moreover, the findings lay a foundation for further studies on the dynamic aspects of various

forms of collaborative innovation, network interactions in innovation processes, and different empirical contexts where the construction industry interplay with other industries in cross industry innovation.

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Author contributions

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Data availability statement

The participants of this study did not give written consent for their data to be shared publicly, so due to the sensitive nature of the research, supporting data is not available.

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