

Framing innovation ecosystems in  
cross-laminated timber  
construction networks

Anna-Lena Gull

Construction management and building technology



# FRAMING INNOVATION ECOSYSTEMS IN CROSS-LAMINATED TIMBER NETWORKS

Innovationsekosystem i nätverk inom byggande med  
korslimmat trä

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# Abstract

Cross-laminated timber (CLT) has emerged as a climate-positive alternative to carbon-intensive building materials. However, its full potential remains underutilized, partly due to low levels of and poorly coordinated system-level resource optimization and innovation. Systemic development of CLT-based construction necessitates collaboration across industries. Although collaboration among specialized contractors and suppliers within single projects is supported by established industry practices, sustained inter-firm collaboration across multiple building projects remains under-investigated. While innovation ecosystem (IE) theory offers a promising framework for examining sustained co-innovation through shared value propositions, existing IE research in construction lacks a practice-based understanding of how organizations execute such collaboration across projects. This thesis addresses these gaps through a dual theoretical stance, combining IE theory to explain what needs to be coordinated across projects with dynamic capabilities (DC) theory to explain how firms develop and enact the necessary capabilities to do so. The thesis explores how firms in CLT-based construction collaborate to innovate and to create and capture value from innovation. The research builds on a six-year (2020-2025) longitudinal study on company networks within CLT-based construction, drawing on data from interviews, focus groups, observations and public documents, retrospectively covering events back to 2013. The findings show that the fragmented, project-based nature of construction requires IE actors to commercialize co-innovated products outside the ecosystem, making IE-specific capabilities for value capture central to competitive advantage. The shared value proposition enables co-innovation, observed in this study, as both building project-initiated and supplier-initiated processes. As products matured and the shared value proposition became established on the market, the focal firm began vertically integrating suppliers, consistent with the long product life cycles characteristic of the construction industry. The findings further describe IE coordination as a superimposed structure on conventional building project organization and activities. These superimposed mechanisms for co-innovation and value capture enable collaboration across multiple building projects through the sharing of resources and risks among IE actors. The thesis contextualizes IEs within project-based on-site construction and within

industrialized house building (IHB). In doing so, it extends IE and IE life cycle theory by conceptualizing IEs as organizational structures superimposed on individual firms and temporary building project organizations. The thesis contributes to IHB theory by introducing an ecosystem perspective to industrialization and enriches construction management literature with a new perspective on network-based approaches to innovation. It also provides a methodological contribution to DC research in construction through a framework for analyzing DCs via their underlying situated practices, and to IE theory through a contextualized method for identifying ecosystems in the construction industry, as well as by testing a longitudinal process approach to analyzing temporal IE development. The managerial implications offer insights for managers in the construction industry seeking to realize the benefits of co-innovation, as well as guidance for policymakers aiming to support network-building among firms pursuing co-innovation and shared value propositions.

**Keywords:** innovation ecosystems, dynamic capabilities, co-innovation, value capture, networks, cross-laminated timber, timber construction

# Sammanfattning

Korslimmat trä (KL-trä) har etablerats som ett klimatpositivt alternativ till koldioxidintensiva byggmaterial. Trots detta är materialets fulla potential ännu inte realiserad. En förklaring är att hinder på systemnivå, särskilt kopplade till bristandesamordning av resurser och innovationsinsatser i byggsektorn. Utveckling av KL-träbaserat byggande förutsätter samverkan mellan aktörer över organisations- och projektgränser. Samtidigt domineras byggsektorn av projektbaserade arbetssätt, där samarbete i huvudsak organiseras inom enskilda projekt, och forskning på långsiktiga och projektöverskridande företagssamarbeten är låg. Innovationsekosystemteori (IE) erbjuder ett analytiskt ramverk för att studera hur aktörer samlas kring ett gemensamt värdeerbjudande och samskapar innovation (eng. co-innovation). Inom byggforskningen saknas dock en praktisk nära förståelse för hur sådana samarbeten etableras, organiseras och upprätthålls över flera projekt. Denna avhandling möter detta genom att kombinera IE teori, som förklarar vad som behöver samordnas, med teorin om dynamiska förmågor (DC), som förklarar hur företag utvecklar och tillämpar de förmågor som krävs för sådan samordning. Avhandlingen undersöker hur företag inom KL-träbaserat byggande samarbetar kring innovation samt hur värde skapas och fångas i dessa processer. Studien bygger på en sexårig (2020–2025) longitudinell analys av företagsnätverk, baserad på intervjuer, fokusgrupper, observationer och offentliga dokument, med kompletterande retrospektiva analyser tillbaka till 2013. Resultaten visar att byggsektorns fragmenterade och projektbaserade struktur innebär att samskapade innovationer ofta behöver kommersialiseras även utanför det enskilda innovationsekosystemet för att få genomslag. Detta indikerar att ekosystemspecifiserade dynamiska förmågor är centrala för att möjliggöra långsiktig konkurrenskraft. Samskapad innovation utvecklas kring ett gemensamt värdeerbjudande och drivs av initiativ från såväl projektorganisationer som leverantörer. Vidare visar resultaten att IE koordinering fungerar som en överlagrad struktur i relation till byggprojektorganisationer. Genom denna struktur möjliggörs projektöverskridande samarbete, där resurser, kunskap och risk delas mellan aktörer. Det verkar vara så att i takt med att värdeerbjudandet mognar och innovationer etableras på marknaden tenderar ledande aktörer att öka graden av vertikal

integration. Avhandlingen bidrar teoretiskt genom att kontextualisera innovationsekosystem inom husbyggande generellt och industriellt husbyggande (IHB) specifikt, samt genom att utveckla förståelsen av innovationsekosystemet som en organisatorisk struktur överlagrad både permanenta företagsorganisationer och temporära projektorganisationer. Vidare bidrar avhandlingen till IHB-forskning genom att introducera ett ekosystemperspektiv på IHB, samt till byggproduktionsforskning genom ett nätverksbaserat perspektiv på innovation. Metodologiskt utvecklar avhandlingen angreppssätt för att studera projektbaserade kontexter över tid. Inom forskning om dynamiska förmågor operationaliseras begreppet genom en analys av underliggande aktiviteter. Detta möjliggör framtida empiriska studier av hur dessa förmågor faktiskt utvecklas och tillämpas i byggkontext. Vidare utvecklar avhandlingen en kontextualiserad metod för att identifiera och avgränsa innovationsekosystem i byggindustrin. Avhandlingen använder även en longitudinell och en processbaserad ansats, som möjliggör analys av i IE utveckling över tid. De praktiska bidragen visar, delvis hur samskapad innovation organiseras inom KL-träbaserat byggande, delvis hur värde kan skapas och fångas i projektöverskridande samarbeten. Avhandlingen ger även rekommendationer till beslutsfattare som har uppdraget att öka samverkan mellan företag i syfte att öka innovationer inom träbyggande.

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*Anna-Lena*

*Falun, April 2026*

# Appended papers

- Paper 1 (P1) Erikshammar, J., Gull, A. L., & Stehn, L. (2024). Innovation ecosystems beyond construction projects—a case study of Swedish cross laminated timber building networks. *Wood Material Science & Engineering* 20(5), 968-980. doi: 10.1080/17480272.2024.2376180
- Paper 2 (P2) Gull, A. L., Erikshammar, J., & Stehn, L. (2026). Dynamic capabilities for co-innovation in timber construction: a case study of Swedish cross laminated timber innovation ecosystems. *Frontiers in Built environment* 12:1783747. doi: 10.3389/fbuil.2026.1783747
- Paper 3 (P3) Gull, A. L., Stehn, L., & Erikshammar, J. (2026). Temporal dynamics of a CLT-based innovation ecosystem: Organizing for co-innovation and value capture over time. Submitted to *Frontiers in Built Environment*, review ongoing.

Author contributions across the three papers:

	P1	P2	P3
Research design	ALG, JE, LS	ALG, JE, LS	ALG, JE, LS
Data collection	ALG	ALG	ALG
Analysis	ALG, JE, LS	ALG, JE, LS	ALG, JE, LS
Writing and editing	ALG, JE, LS	ALG, JE, LS	ALG, JE, LS

ALG = Anna-Lena Gull, JE = Jarkko Erikshammar, LS = Lars Stehn



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# INTRODUCTION

*This thesis examines how companies engage in CLT-based construction as a system spanning multiple building projects, drawing on co-innovation within innovation ecosystems and dynamic capabilities. CLT-based construction is introduced to describe CLT as both an industry and a material, together with the components and solutions as a system developed alongside it in practice. One view focuses on the value chain, including the industry structure and its actors. The other focuses on the systemic dimension where components and solutions are coordinated through innovation ecosystem collaboration, in which firms mobilize capabilities within and between projects.*

## *Research gap 1: The CLT value chain: from sawmills to system suppliers*

*The first gap concerns the structure and incentives of the CLT industry. It addresses how the material and its value chain are organized, the roles assumed by different actors, and where standards and practices are lacking. It also considers why traditional approaches such as vertical integration have struggled to deliver consistent outcomes for CLT-based construction.*

The United Nations climate conference COP21, held in Paris in 2015, was a major milestone in raising sustainability awareness in the construction industry. The sector accounts for a substantial share, approximately 21 %, of the global greenhouse gas emissions (United Nations Environment Programme, 2024), thereby prompting decisive actions by all stakeholders. To meet the global

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sustainability goals, both incremental and radical innovations, such as new building systems and production processes, are required (Häkkinen & Belloni, 2011).

Timber, in particular cross-laminated timber, (CLT) has been recognized as a climate-positive substitution for more carbon-intensive, building materials (Ilgin et al., 2023b; UNECE/FAO 2021). Research examining the life-cycle performance of different building systems has verified the carbon benefits of timber structures (e.g., Hill, 2019; Younis & Doodoo, 2022) and has contributed to an industry-wide discussion that extends beyond the choice of materials to include the climate effects of optimizing timber building systems for more efficient use of raw materials and other resources. This is particularly important for CLT, which consumes comparatively more timber than light-weight structures. One motivator for timber, and CLT in particular as a massive product, in construction has been its potential to store carbon in buildings, thereby mitigating the carbon impact of other building materials (Hämäläinen & Salmi, 2023). However, encouraging high volumes of timber introduces a risk of sub-optimizing other environmental targets. Optimization, where components are selected based on their technical contribution rather than path dependency within individual companies, necessitates co-innovation and operational collaboration among suppliers. CLT-based construction thus entails more than building with CLT; it is a building practice that integrates CLT with components and services from multiple suppliers, aiming to enhance overall resource efficiency in buildings.

While optimization of timber structures offers clear sustainability benefits, the primary driver for companies to engage in optimization is economic value, as some stakeholders benefit from reduced material consumption and more streamlined processes (P2). However, CLT-producing companies often have limited economic incentives to pursue these developments, due to the predominance of volume-based pricing models (P2). Combined with their limited experience in building projects, this raises important questions on how co-innovation and optimization of CLT-based construction should be organized, and which actor(s) should take a leading role. Moreover, the fact that the CLT producers are typically much larger companies than their customers (i.e., building contractors) highlights the need for collaborative models that balance bargaining power.

CLT producers have pursued a range of market and collaboration strategies, spanning roles from material suppliers of precut components to full design-assembly partners for main contractors (Larasatie et al., 2020). Experimental

efforts have also been made to standardize CLT components for off-the-shelf delivery to building projects. At the same time, the performance of CLT is highly dependent on integration with complementary materials and products, as well as on effective design, planning, and project execution (Hämäläinen & Salmi, 2023; Said et al., 2025). In some cases, this has resulted in CLT producers developing building systems composed of components from their own product portfolios. Concurrently, producers of complementary products, such as insulation, fasteners, fire protection products, and related components, have independently developed specialized products adapted to CLT-based construction in general (P2). However, a lack of common standards for both the production of and building with CLT remains evident (Kurzynski et al., 2022), contributing to coordination and design challenges across the CLT-based construction value chain that ultimately hinder the co-innovation of building systems necessary for resources optimization.

Industrialized house building, where a focal company acquires control over its supply chain through vertical integration, and develops a standardized product, commonly multi-family housing for on-site assembly, is an established approach in Sweden to address fragmentation in timber construction (Lessing et al., 2015; Stehn et al., 2021). This business model has also been tested within CLT-based construction. Examples include Swedish companies Nock massiva trähus and Sizes, both of which were liquidated (Sizes in 2022 and Nock in 2023), the UK-based social housing company Legal & General homes, that chose not to start up their production line for CLT around 2019, and the U.S. company Kattera, whose aggressive investments in early vertical integration were not balanced against sales and project execution, leading to bankruptcy in 2021 (Brown, 2025). These companies were dependent on external sawn timber supply (L&G homes and Kattera) or precut CLT-elements (Sizes and Nock). These outcomes suggest that a modified business model for industrialized house building is probably needed for CLT-based construction.

*In conclusion, this industry picture emphasizes the need for organizational solutions beyond pure vertical integration and calls for approaches that can sustain coordination, standardization and risk sharing when CLT-based building systems are developed and tested across projects.*

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### *Research gap 2: CLT-based construction as a system: company interdependencies and capabilities*

*The second gap addresses CLT-based construction as a system where components and processes must be co-developed through alignment among actors across projects. In this setting, innovation ecosystems and dynamic capabilities may provide viable organizational approaches for enabling and implementing co-innovation.*

Development of building systems enabling resource-optimized CLT-based structural framings appears to be a feasible sustainable pathway in timber construction, representing a natural progression from substituting carbon-intensive materials with timber. However, prior industry developments highlight the need for collaboration among interdependent actors within the CLT-building supply chain. This need is further amplified by the fragmented and project-based nature of the construction industry, where specialized companies are assembled into temporary teams for each building project and disbanded upon completion, thereby hindering learning and innovation over time (Hughes & Stehn, 2019).

Common approaches for stimulating innovation in construction industry include project-based contract management (Hughes & Stehn, 2019), project management practices (Eriksson, 2013; Larsson & Larsson, 2018), and supply chain or team integration within projects (Hall et al., 2018; Ozorhon et al., 2014), all of which operate at the level of temporary project teams. Network-based collaboration (Havenvid et al., 2017) is another approach used to examine opportunities for sustained resource sharing, learning and innovation adoption across multiple projects. While this approach provides interesting insights into how construction companies maintain relationships as business networks across projects, it lacks the focus on co-innovation and the development of a shared value proposition for implementing new, sustainable practices and technical solutions. More recent network-based innovation research by Happalad et al. (2026) has illustrated how a cross-industrial co-innovation network can support service innovation in construction logistics. The stand-alone innovation outcome was, however, commercialized by a single company, and the network was dissolved following the market launch of the new service.

In other industries, the concept of innovation ecosystems (IEs) has been applied to enable rapid, systemic innovation and its commercialization through

ecosystem-based shared value propositions (e.g. Adner & Kapoor, 2010; Adner, 2016; Jacobides et al., 2018). The main difference between the IE and the previously discussed collaboration mechanisms in the construction industry lies in the existence of a sustained, shared, value proposition. This implies that the IE collaboration extends across building projects (P1) and involves both co-innovation and joint marketing and sales efforts (P2). In a construction industry context, the IE concept is therefore a relevant theoretical lens for examining how supply chain collaboration can be structured and sustained across projects, without requiring the investments in vertical integration characteristic of established business models in industrialized timber house building (Lessing et al., 2015).

While the IE perspective offers a promising lens for examining the structure and mechanisms for implementing co-innovation, research on IEs in construction lacks a complementary perspective on how such collaboration is operationalized by organizations. For change to occur, it is not sufficient to understand what should be done, it is also necessary to understand how it can be achieved in practice. To address this, dynamic capabilities (DC) theory (Collis, 1994; Teece et al., 1997; Teece, 2007) can be applied to analyze how capabilities for leveraging the interconnectedness within an IE are developed among participating actors. DCs are described by Teece (2007) as capabilities that enable firms to build, integrate, and reconfigure resources and routines to remain competitive in dynamic environments. They exhibit significant contextual dependence (Schilke et al., 2018) as well as temporal dynamism, as their development reflects the challenges and opportunities present at a given point in time. In the construction context, however, this perspective has been criticized for its perceived elusiveness, and suggested that DCs should be seen as enacted practices stemming from opportunistic, path-dependent actions rather than strategically developed, explicit capabilities (Green et al., 2008). This thesis responds to that critique by tracing DCs through observable activities performed by IE actors within and between projects, rather than treating them solely as strategic constructs.

*This leads to a dual theoretical stance in the thesis, in which innovation ecosystems explain what needs to be coordinated across projects through a shared value proposition, while dynamic capabilities explain how companies achieve this through capabilities enacted within and across projects.*

## INTRODUCTION

### *Aim and research strategy*

The aim addresses the two research gaps from a company-level perspective. The thesis investigates how companies can organize collaboration across projects to realize CLT-based construction as a system through innovation ecosystems and dynamic capabilities. Here, ‘organize’ encompasses both the organizational structure and its operational implementation and development. This aim is addressed by the following overarching research question:

*How can company collaborations within CLT-based construction be organized to support innovation and implementation across building projects?*

To investigate this comprehensively, and to provide insights into both research gaps, namely, identifying operational solutions for collaboration and co-innovation among interdependent companies on one hand, and across building projects on the other, the research question was divided into four sub-questions:

1. What are the motivators for co-innovation for companies within CLT-based construction?
2. What determines the boundaries for co-innovation in CLT-based construction?
3. How can collaboration be structured and managed over time?
4. What capabilities can be developed by companies to benefit from collaboration?

The chosen methodological design is intentionally temporal, to capture IE life cycles, and practice-centered, to identify DCs as enacted activities that link company actions to IE development, thereby directly addressing the two research gaps. The research was conducted as a six-year (2020–2025) qualitative longitudinal case study of firm networks collaborating on systemic solutions for CLT-based wooden structural framings. The case selection followed a favorable case strategy (Flyvbjerg, 2006), motivated by the studied networks being primarily situated in a Swedish region characterized by long-standing building of competence and production capacity in timber construction, further reinforced by early policy initiatives promoting the use of timber in public building projects. Data were collected through multiple methods, including 48 individual interviews and two group interviews, 11 focus groups, and approximately 1200 hours of participatory observation and 22 public documents, covering the period

from 2013 to 2025. Some data were analyzed in more than one paper, approached from different theoretical perspectives. Data analysis employed different methods across the three appended papers, each selected for its suitability in addressing the respective research questions: social network analysis (Scott & Carrington, 2023) for identifying inter-firm linkages and networks (P1), reflexive thematic analysis (Braun & Clarke, 2006; Braun, 2021) for tracing dynamic capabilities within the networks (P2), and visual mapping combined with temporal bracketing (Langley, 1999) to analyze activities as process data within a timeline incorporating lifecycle phases of the network (P3).

### *CLT as a building component and its previous industrial developments*

CLT is a cross-laminated wood product, normally built up of three to eight layers glued at 90 degrees angles to each other, with some exceptions where certain panels include parallel layers included within the crosswise glued structure. The structural benefits of cross-lamination include increased dimensional stability in all planes, improved load-bearing properties both in and out of plane, and the possibility to produce large elements (Brandner et al., 2016), reaching dimensions of up to 3,5 x 20 m, with thicknesses ranging from 60 mm to 300 mm. Additional benefits arise from its prefabrication into precut elements ready for on-site assembly, the efficient processing of openings through CNC machining, and the integration of other materials such as glue-laminated timber, steel, or even concrete slabs in hybrid floor systems.

The main contribution of CLT to sustainable construction is primarily attributed to its structural capabilities, which enable the construction of large and complex buildings in timber (Ilgin et al., 2023b), thereby extending the use of timber to a broader segment of the construction market. CLT was initially developed in the mid-1990s by Central European sawmilling industry as a means of adding value to low-grade sawn timber (Brandner et al., 2016). As the product began to gain market traction around 2015 (Muszynski et al., 2017; Muszynski et al., 2020), although still a niche product, sawmilling companies in other regions also invested in CLT production (Muszynski et al., 2017). In doing so, these companies adopted a new role as suppliers of building components rather than solely raw materials, as a shift driven by forward integration into value-added production (Brege et al., 2010; Packalen et al., 2017). More recent developments have further emphasized the integration of supplying sawmills with CLT factories,

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to benefit both from a stable and economically predictable raw material supply (Ilgin et al., 2023a) and a reduced need for trimming sawn timber of varying qualities. This development describes an “inside-out” perspective that has largely dominated the supply of CLT elements to the construction market.

The design and planning process of a CLT structure is tightly integrated with both CLT production and the assembly plan of the building site. CLT elements are tailored to specific positions within the building. Typically, no two elements are identical, considering not only geometry but also cut-outs for installations and connectors. To ensure project efficiency, the elements must therefore be loaded onto trucks in the sequence required for on-site assembly. This requires close interaction and coordination between the CLT producer and the building project organization, involving not only the customer but also complementary actors such as structural engineers and technical consultants, as described in general terms by Dubois and Gadde (2000) regarding coordination within building projects.



*Figure 1. Assembly of a CLT flooring panel. Photo: ByggPartner i Dalarna AB.*

Lately, CLT has been integrated into prefabricated volumetric timber construction, or industrialized timber house building (IHB). Following changes to Swedish building codes in 1995 that permitted wooden buildings of three storeys and higher, IHB was increasingly adopted by builders seeking more stable

processes and business models (Brege et al., 2014), thereby playing a substantial role in the market development of timber construction in Sweden.

In IHB, a focal actor develops prefabricated housing intended for on-site assembly (Höök & Stehn, 2008; Meiling et al., 2013), delivered as volumetric or panel elements depending on the production and market strategy. IHB companies develop building systems, often manifested as product platforms, which enable standardization of design and production through transferring knowledge across projects (Jansson et al., 2014; 2015). IHB involves vertical integration to increase control over the supply chain and the building system (Lessing et al., 2015).

Research on IHB has focused on exploring and explaining trade-offs between standardization and flexibility (Jonsson & Rudberg, 2014), as well as the development of platforms designed for targeted market segments (Jansson et al., 2014; 2015; Jonsson & Rudberg, 2014), encompassing both product and process development (Costa et al., 2025). IHB has also demonstrated positive productivity gains, explained by efficient use of the pre-designed platforms (Stehn & Jimenez, 2023), and been conceptualized as a manifestation of dynamic capabilities at the firm level (Stehn et al., 2021).

IHB companies have integrated CLT into their existing platforms as a building component to reinforce otherwise lightweight structures, while other, more specialized IHB startups have adopted CLT as the primary structural material, developing new platforms based on rigid CLT volumes. The latter group has encountered market difficulties, in some cases leading to liquidation or strategic repositioning. Overall, more successful initiatives appear to have used CLT as a complementary component within established building systems, whereas attempts to establish a CLT-dominant prefabricated modular building system have faced greater challenges.

This trajectory illustrates how the innovation of CLT has evolved, with various industrial actors independently experimenting with different approaches, from integrating the product into existing building systems to developing stand-alone CLT-dominant building systems. It also highlights the challenges that arise when new actors attempt to position themselves within established construction processes.



# THEORETICAL APPROACH

## *Conceptualization of CLT-based construction*

CLT is not a building system by itself, even though producers and trade associations have developed comprehensive technical guidelines for designing and building with CLT. Complementary products and services that significantly impact the performance of a CLT structure lie outside the scope of the CLT producers' operations. To mitigate project-related risks associated with this, the technical guidelines typically provide general guidance on acoustics, fire protection, and structural calculations.

This interdependence between components is described in construction research on systemic innovation, a concept applied as a theoretical lens when studying both full-scale building projects (Hall et al., 2018), including cases such as multi-storey timber buildings (Lindgren & Emmitt, 2017) and green buildings (Katila et al., 2018), as well as more bounded technical systems within buildings, such as prefabricated MEP-systems (mechanical, electrical, plumbing) (Lavikka et al., 2021). These studies share a common focus on component interdependencies brought together into a system by a focal actor (Rutten, 2009). Among these, the study by Lavikka et al. (2021) most closely resembles CLT-based construction, as both involve the integration of specialized subsystems within a broader construction context.

Unlike traditional IHB, where the product platform is designed for a niche type of building (Lessing et al., 2015), typically residential, CLT is predominantly

## THEORETICAL APPROACH

used in traditional on-site construction. In such settings, building geometries do not support standardized prefabrication to the same extent, and the challenges of fragmentation are more pronounced than for IHB. Consequently, components and component-based building systems must be designed to accommodate a wide range of project configurations (Dubois & Gadde, 2000;2002).

Efforts have so far, in line with Dubois & Gadde (2000;2002), primarily focused on developing CLT as a product that fits a broad but non-specialized range of project configurations. However, the value of systemic innovation lies in the interconnectedness of components and services, which, when integrated into a system, can generate more value than stand-alone products applied in fragmented projects (Hall et al., 2018).

When systemic innovation is viewed solely as a technical solution, challenges arise in its implementation (Hall et al., 2018; Lavikka et al., 2021; Uusitalo et al., 2024). Consequently, the CLT-based building system would benefit from a complementary organizational structure that integrates business and innovation collaboration, supported by capabilities that both exploit and develop this collaboration and the associated systemic innovation. Furthermore, the agreements governing such collaboration need to be sufficiently open to allow participating companies to market their individual innovations to the broader construction market (P1 & P2), thereby avoiding volume-constraining lock-in effects associated with the limited scaling capacity of a single focal firm.

In summary, CLT-based construction is here conceptualized as a holistic approach grounded in balanced interdependence among companies and components, aimed at systemic value creation in building projects, and a shared commitment to co-innovation within and between projects for the benefit of the system.

### *Innovation ecosystems as collaborative structures for systemic innovation*

This thesis focuses on systemic innovation as a realized innovation output, that is, the integration of co-dependent products and services into a larger solution-; CLT-based construction. This follows Teece (1986), who argued that systemic innovation depends on complementary products or services that form part of a broader system, in contrast to autonomous innovations that can operate independently. This interdependence is also expressed through a *focal value proposition* in innovation ecosystems theory, which posits that innovations

brought to the market by innovation ecosystems are systemic by nature, leveraging interconnectedness to align multiple actors' offerings around a joint value proposition (Foss et al., 2023; Jacobides et al., 2018; Kapoor, 2018), consistent with the structure of innovation ecosystems introduced by Adner (2016).

This does not imply, however, that all systemic innovations are executed through IEs. The distinction lies in the alignment structure of the IE, where a focal actor strategically manages the roles and positions of a selected set of partners (Adner, 2016). While systemic innovation depends on complementary innovations, its definition does not necessarily extend to include the strategic management of partnerships between actors providing these complementarities. When properly managed, the total value captured from the value proposition of the IE is larger than the sum of all complementarities (Baldwin et al., 2024).

The definition of an IE used in this thesis was proposed by Adner (2016, p.42) as follows: '*...the alignment structure of the multilateral set of partners that need to interact in order for a focal value proposition to materialize.*' Ecosystem research may adopt broader definitions (Pulkka et al., 2016), and accordingly, IE theory has been applied to study both broad and more specific construction innovation processes, such as addressing large-scale societal challenges (Havinga et al., 2023), examining technical solutions within smart city initiatives (Linde et al., 2021), and analyzing collaboration structures for CLT-based construction (P1).

The fragmented nature of the construction industry, and more specifically the limited scaling capacity of a single focal firm, suggests that an IE approach of tightly aligned partners providing IE exclusive products or services might not be feasible in this context. Previous applications of the ecosystem concept in construction management research remain somewhat fragmented, and a clear direction within the field appears to be lacking (Vigren, 2024). Pulkka et al. (2016) proposed a framing of ecosystems in construction based on a broader definition, suggesting that any network, from isolated innovation efforts to regular building projects, can be analyzed as an ecosystem, drawing on the inherently collaborative and temporary structure of value creation within construction projects. This interpretation has been adopted by subsequent scholars (e.g., Poblete et al., 2022; Toppinen et al.; 2022; Viholainen et al., 2021) when applying the ecosystem lens to collaborations within individual projects. Havinga et al. (2023) extended this perspective by comparing project- and product-based approaches, while Vosman et al. (2023) applied a similar approach (P1), focusing on collaborations spanning multiple projects. These perspectives open up

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alternative interpretations of ecosystems in construction. Vigren (2024) further advanced the discussion initiated by Pulkka et al. (2016) by highlighting the challenge of using building projects as ecosystem boundaries, given the independence of actors in projects. As such, construction research lacks robust tools for identifying and delineating ecosystem boundaries (Vigren, 2024), in contrast to the more clearly defined partners roles and interdependencies emphasized in business strategy-oriented IE research (e.g., Adner, 2016). A theoretical implication of this thesis is therefore to provide empirical insights from a construction context, contributing to the further development of IE theory by accounting the role of building projects in defining ecosystem boundaries. To understand these implications, three core elements of Adner's (2016) definition, alignment structure, multilaterality and a focal value proposition, need to be explained in the context of CLT-based construction:

**Alignment structure** refers to the positions and roles that IE actors agree upon. This encompasses both the formal structure and the actions that are taken within the IE to ensure that all actors contribute to the focal value proposition and shared objectives. In CLT-based construction, roles and positions are typically delineated according to standardized structures within building projects. However, actors may occasionally or permanently extend their roles, described as 'role extensions' (P1). Such extension may be perceived as hostile when they render other actors obsolete, or non-hostile when actors temporarily assume additional roles to balance resources (P1). Alignment within building projects thus relies on industry standards, while alignment in co-innovation across projects emerges predominantly from actors' initiatives (P2 & P3).

**Multilaterality**, refers to the interdependence among actors and their individual value propositions. An IE constitutes a network of actors and activities organized to extend beyond traditional bilateral supplier-customer relationships. Actors without direct contractual agreements may still significantly influence on each other's ability to capture value from the IE (Kapoor, 2018). The underlying synergy principle of multilaterality is that  $1+1>2$ . In the construction industry, some innovation barriers related to fragmentation stem from interdependent building components that require coordination, yet communication between suppliers often remains confined to bilateral contractual relationships. This can lead to suboptimization and limited knowledge exchange among suppliers with interdependent products and services. Addressing these interdependencies requires multilateral linkages among suppliers.

A **focal value proposition** is a shared systemic value proposition developed around a focal innovation. It delineates the IE, within which the individual value propositions of all actors are expected to contribute to enhancing the overall value. To remain competitive, all components must be continuously developed. In this thesis, CLT constitutes the focal innovation around which the value proposition of CLT-based construction is built. However, the competitiveness of the examined IEs' value propositions appears to be primarily to be capability-based, as the individual components are not exclusive to the IE due to the fragmented structure of the construction industry (P2).

The IE structure by Adner (2016) builds on the concept of business ecosystems, introduced by Moore (1993). Moore also proposed a lifecycle framework for ecosystems, spanning stages from birth and expansion to leadership and eventual renewal or decline. This perspective suggests that an IE is a dynamic form of collaboration that evolves in purpose and structure over time.

As this thesis builds on a longitudinal study of IEs, IE lifecycle theory has been applied to investigate temporal changes in the organizing of actors and their co-innovation activities throughout the study period. Previous research on IE lifecycles has focused on orchestration (Autio, 2022), roles (Dedehayir et al., 2018), and governance mechanisms for value creation and value capture across different stages of maturity (Ben Letaifa, 2014; Ketonen-Oksi & Valkokari, 2019; Ritala et al., 2013), highlighting challenges related to competition over value capture among IE actors. Foss et al. (2023) further suggest that IE leader(s) may be motivated by their advantageous position in value capture. Nevertheless, a more equitable distribution of value capture across actors has been identified as an important motivator for participation in an IE (P1), extending beyond monetary exchange in building projects to include scaling benefits, shared routines and resources, and co-innovation (P2).

## *Dynamic capabilities*

Dynamic capabilities have been highlighted as capabilities that enable firms to remain competitive by adaptively altering their resource base in response to changing environments, rather than relying on static market positions (Teece et al., 1997). These capabilities form the foundation for activities aimed at acquiring

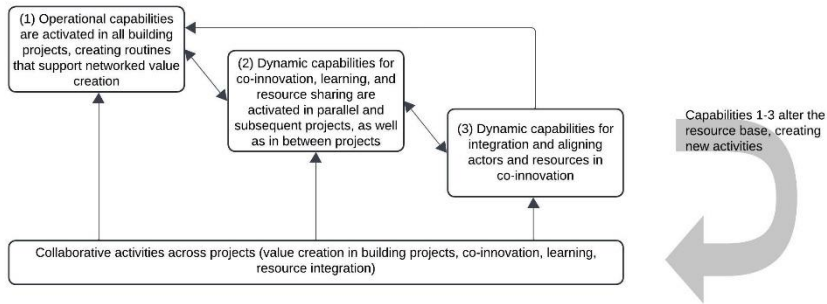
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and developing internal and external resources and can be described as routinized activities for enabling change (Stadler et al., 2013).

DCs themselves can be developed through other capabilities, often referred to as higher-order dynamic capabilities (Schilke, 2014b). A four-level framework proposed by Collis (1994) describes the interaction between higher- and lower-order capabilities. At the lowest level are operational capabilities encompassing the routines and processes organizations use for their daily operations (Winter, 2003). In the construction sector, these are performed through well-established routines and roles that facilitate project delivery and collaboration (Bygballe et al., 2016). At the second level are DCs, which enable continuous improvement and adaptation of operational routines (Teece et al., 1997). The third level comprises DCs for strategic development and resource integration. At the highest level are the higher-order DCs, which are employed for development of the lower-level DCs through a 'learning to learn' approach (Collis, 1994). These higher-order DCs adopt a broader perspective on the learning and development processes underlying lower-order DCs (Schilke, 2014).

Teece (2007) positioned DCs as critical for shaping and profiting from the ecosystem in which an organization operates, emphasizing the importance of integrating external resources. As noted by Schilke *et al.* (2018) DCs exhibit a significant contextual dependence, and therefore require specification for applications. Since DCs are expected to enhance firm competitiveness, in line with the resource-based view, there can be no universally applicable sector-specific DCs, as firms compete based on their unique resource configurations (Collis & Anand, 2021). Consequently, contextualization must be fine-grained, reflecting the specific conditions of companies and their networks. This can be supported by Teece's (2007) microfoundational framework, which provides a structured, yet general, account of the underlying elements of DCs, such as routines, processes and activities, that can be further adapted into actor-specific activities and resources.

A contextualized explanation of the interactions between activities and capabilities was developed in (P2). Figure , included in (P2), illustrates the three levels of capabilities (drawn from Collis, 1994) that were expected to be identified through observing activities that indicate DCs in use, in the case study. In this figure, the activities performed by the IE actors within and between building projects are presented both as drivers of capability development, and as outcomes of exercising newly developed capabilities within the IE.



*Figure 2. The three capability levels as concurrent and interdependent layers shaped by activities across projects. Arrows indicate influence or mutual influence. (P2)*

However, the application of DC theory in construction research is not without critique. Green et al. (2008) argue that DCs are difficult to empirically observe in construction due to the sector’s fragmented and temporary nature. Rather than existing as stable, transferable assets, DCs often manifest as activities embedded in actor interactions within projects. Recent construction literature acknowledges this context dependence, and DCs are therefore increasingly examined within isolated applications rather than at an aggregated industry level (Li et al., 2025; Robson et al., 2024). Given the project-based nature of construction, capabilities must address the needs of both the temporary (project-based) and the permanent organization (Adam and Lindahl, 2017), enacted by loosely connected actors (Green et al., 2008). This suggests that DCs in construction may be developed both within individual firms and as shared capabilities across collaborating organizations.

The concept of collectively shared and developed DCs has been introduced in literature as alliance-based learning capabilities (e.g., Dyer & Nobeoka, 2000; Manley & Chen, 2015) and has also been explored in the context of new product development in alliances (Schilke, 2014a). Notably, DCs can be analyzed at multiple levels, ranging from the individual to the organizational and extending beyond firm boundaries (Schilke et al., 2018), making them applicable to inter-organizational settings such as construction. Building projects require collaboration between multiple organizations (Harty, 2005), necessitating capabilities for effective synchronization, alignment, and adjustment of contributions from multiple project partners (Bygballe et al., 2016). Building contractors often rely on subcontractors to access specialized capabilities.

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However, managing an increasing number of subcontractors requires strong coordination and management capabilities (Green et al., 2008). In traditional construction practices, learning, understood as a capability that builds lower-level capabilities, is often informal and ad hoc (Kamara et al., 2002), in contrast to the cumulative capability development observed in the more stable supply chains of IHB (Stehn et al., 2021). By situating DCs within an IE perspective, it becomes possible to explore how such capabilities emerge as shared, enacted practices within the fragmented and project-based logic of construction.

### *Capability-driven innovation ecosystems within CLT-based construction*

To investigate the research questions of this thesis, a dual theoretical stance is adopted: IE theory to understand how to structure co-innovation of component-based building systems and their implementation across building projects, and DC theory to analyze how operations within the IE can be developed to realize its benefits. These benefits include risk-sharing, especially in early phases of development (Adner & Kapoor, 2010) and the possibility to share and utilize resources with partners (Teece, 2007).

These frameworks draw on two interrelated strands of literature based on the resource-based view of DCs and of IEs. These two perspectives are treated as complementary analytical lenses that together enable a multi-faceted understanding of what needs to be coordinated across projects and to explain how companies develop and enact the necessary capabilities to do so. The theoretical perspectives were not merged; rather, they were combined to provide a richer understanding of the two research gaps. Together, these theoretical frameworks underpin the view presented in Figure 3, where co-innovation is driven by motivation to collaborate, a shared value proposition, an enabling organizational structure, and DCs that develop the routines and skills required to realize benefits over time.

In this study, the overarching research question is positioned within DC and IE theory through the four underlying research questions, presented in Figure 3 as key mechanisms shaping collaboration.

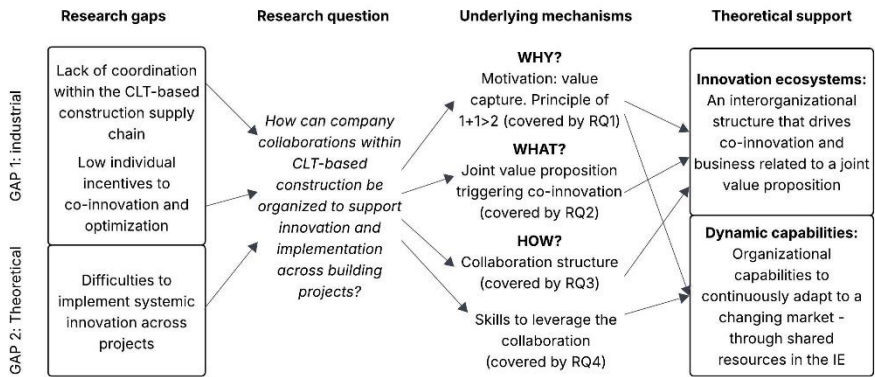


Figure 3. Theoretical framing of the research questions.



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## *Research design*

The overarching research question of this doctoral thesis - *How can company collaborations within CLT-based construction be organized to support innovation and diffusion across building projects?* – has been explored through three papers, all employing single case studies for exploratory purposes (Yin, 2018). A favorable critical case approach (Flyvbjerg, 2006) was applied to delineate the case boundaries, with theoretical sampling of actors in (P2) and (P3) (Eisenhardt & Graebner, 2007), to support the revelatory intent of this research approach and to enable theory building.

The main contributions and theoretical frameworks of the appended papers are presented in Table 1. A more detailed description of their contributions is provided in section 4. The thesis has been cumulatively built through the individual contributions of the included papers' case studies (Voss et al., 2002), with the aim of supporting theory building (Eisenhardt, 1989; Voss et al., 2002). P1 established a foundation for subsequent IE-based research by identifying and describing IEs within CLT-based construction. P2 examined how IE actors individually and collaboratively developed capabilities to capture value from the IE. P3 analyzed the organizational development of the IE across its full lifecycle in relation to co-innovation, value creation and value capture, and investments. To investigate these perspectives, data accumulated across all papers were analyzed using different methodological approaches, each selected to generate relevant and complementary insights.

*Table 1. Theoretical frameworks and contributions of the appended papers to the four thesis research questions.*

<b>Paper</b>	<b>Theoretical framework(s)</b>	<b>Research question(s)</b>	<b>Contribution to thesis research questions 1-4</b>
1	Innovation ecosystems	1. How can innovation ecosystem structures be identified in construction with CLT products? 2. How do niched innovation ecosystems interact with CLT-based building projects?	Framing innovation ecosystem within CLT-based construction (RQ3) Establishing evidence of IE continuity across multiple building projects (RQ3) Illustrating a value proposition for CLT-based construction (RQ2) Identifying expected value capture as motivator for IE participation (RQ1)
2	Innovation ecosystems and dynamic capabilities	How do dynamic capabilities support CLT-based co-innovation within and across building projects?	Identifying a set of capabilities (RQ4) developed by IE actors for co-innovation, implementation and value capture (RQ1)
3	Innovation ecosystem lifecycle	How does the organizing of an IE in construction evolve over time, in relation to co-innovation processes and corresponding value capture?	Providing evidence of the IE collaboration gradually shifting toward a vertically integrated supply chain. (RQ3)

### *Case and context*

The doctoral research was designed as a single-case study, with one of the appended papers applying a longitudinal approach to address the dynamics and development of the IE (Phillips & Ritala, 2019). The case boundary applied in the first two papers were defined as CLT-based construction within a region in mid-Sweden, while P3 narrowed the focus to a specific network of companies within this region, identified in P1. The single-case approach was selected to enable in-depth exploration of the dynamics between actors within the region (Yin, 2018), supported by theoretical case selection guided by the expectation of theory-building insights (Eisenhardt, 1989). Furthermore, the case was both assumed and confirmed in the papers to represent as a favorable critical case for studying IEs engaged in co-innovation and collective capability development in CLT-based construction, following the principles developed by Flyvbjerg (2006).

These principles build upon the assumption that if the investigated phenomena exists, indications are likely be found within a favorable case context, conversely, if the phenomena are not observed in the favorable case context, they are unlikely to be found elsewhere. The classification of the selected region as favorable critical case was motivated by its longstanding collaborations among firms, as well as investments in capacity for CLT-based construction, supported by early policy initiatives at the municipal and regional levels. These conditions were assumed to provide a nationally unique supportive environment for both collaboration and innovation, thereby increasing the likelihood of identifying IEs in CLT-based construction.

The analysis in this thesis is conducted at the network level. Accordingly, the organizations included in the study were selected to reflect a broad range of actors within the CLT-based construction supply chain, to represent the IEs as comprehensively as possible. The initial theoretical sampling (Eisenhardt & Graebner, 2007) of actors was based on a set of companies identified through a social network analysis in P1 focusing on companies involved in all larger CLT-based building projects in the region during a two-year period (2021–2022). The level of interconnectedness (i.e., degree centrality, following Scott & Carrington, 2023), in combination with prior observations, guided the selection of individual companies. In subsequent studies (P2 and P3), complementary organizations were included in the sample to capture challenges related to complementary innovation, as identified in the industrial background of the introduction. The organizations included are listed in

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Table 2, along with their positions as either upstream suppliers, downstream complementors, upstream complementors, or customers within building project deliveries, illustrated in Figure 4. A downstream complementor delivers a product or service to the building project that is integrated into the CLT-based structure after assembly, whereas an upstream complementor provides products or services that influence the CLT-based structure prior to assembly, or even prior to procurement. Supporting organizations are positioned outside the project supply chain for CLT-based construction. The findings in P1 further revealed that some organizations were part of two competing, overlapping IEs.

*Table 2. Actors included in the study, categorized by their roles and positions within the CLT-based construction supply chain.*

<b>Actor by its role</b>	<b>Code</b>	<b>Position</b>
Framing contractor A	FCA	Focal firm
Framing contractor B	FCB	Focal firm
Framing contractor C	FCC	Focal firm
CLT producer A	CLTA	Supplier
CLT producer B	CLTB	Supplier
Glue laminated timber producer	GLT	Supplier
Prefabricated wooden components producer A	PrefabA	Supplier
Prefabricated wooden components producer B	PrefabB	Supplier
Assembly	Ass	Supplier
Fire protection products producer	FP	Downstream complementor
Insulation producer	IP	Downstream complementor
Membranes producer	MP	Supplier/Downstream complementor
Architect A	AA	Upstream complementor
Architect B	AB	Upstream complementor
Structural engineer A	SEA	Supplier
Structural engineer B	SEB	Supplier
Technical consultant	TC	Upstream complementor
Main contractor A	MCA	Customer
Main contractor B	MCB	Customer
Real estate developer A	REA	Customer
Real estate developer B	REB	Customer
Business promotion organization A	BPOA	Supporting organization
Business promotion organization B	BPOB	Supporting organization

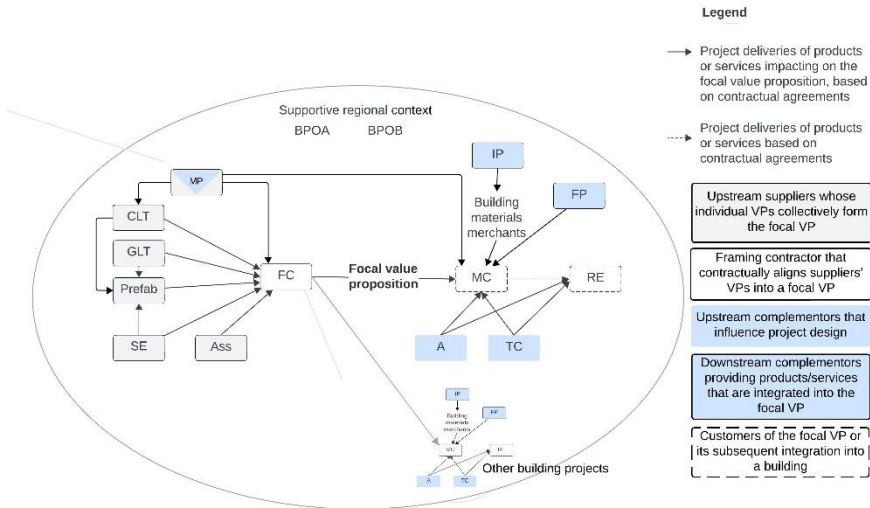


Figure 4. IE roles and positions illustrating with the contractual supply chain across building projects in the regional context. Figure adapted and refined from (P1) and (P2).

### Data collection

Data was collected using multiple methods, including observations, semi-structured interviews, focus groups and documents. The methods were selected by their complementary contributions to capture different types of data:

- observations to create an understanding of the context and the phenomena,
- telephone interviews for collecting information on contractual links,
- focus groups for validation, semi-structured interviews for gaining deeper information on capabilities, activities and strategies,
- and documents for tracking strategic decisions and milestones within the IEs.

This multi-method strategy also enabled data triangulation (Eisenhardt, 1989), supporting consistency across sources. For example, by validating interview data against a press releases or, iteratively, by reflecting on interviews through observations and conducting follow-up interviews for clarification.

Some data were used in more than one paper, analyzed from different analytical perspectives and theoretical frameworks. This was made possible by my dual researcher role as both data collector and analyst, which enabled understanding and in-depth familiarity with the material alongside a comprehensive understanding of the dataset as a whole. This detailed and contextual knowledge was essential for reanalyzing the data through different theoretical lenses, a process that would have been considerably more challenging without such firsthand contextual insights.

All data collection activities and their inclusion in the three papers is summarized in Table 3. All IE actors in

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Table 2 were included as informants in the data collection, along with representatives from other organizations within timber construction. Some of non-IE respondents were included in the early stages of the research to inform decision regarding case boundaries, while others provided external perspectives from organizations, such as construction management professionals or potential customers, interacting with the IE or its value proposition.

*Table 3. Data collection activities accumulating data across all three papers.*

<b>Method and activity</b>	<b>Purpose</b>	<b>Organizations involved</b>	<b>Duration</b>	<b>Papers</b>
Participatory observations	Contextual understanding of research design and triangulation	>30 projects, including >40 organizations	16 months, approx.. 1200 hours. Aug 20 – Nov 21	P1, P2, P3
Observations through interviews in pre-study (12)	Mapping the process and roles in CLT-based construction	MCA, SEA, SEB, FCC, CLTA, + structural engineer	Sep-Oct 2021	P1
Observations (2 seminars)	Gathering information on co-innovation activities and motivators.	Seminar 1: AA, FCA, CLTA, CLTB, MP, BPOB + main contractor, test institute, 2 technical consultants Seminar 2: CLTA, MP,FCA, REB, BPOA	Seminar 1: 2 hours. Aug 23 Seminar 2: 45 min. Sep 23	P2
Observations	Identifying on-going co-innovation activities.	All	2022-2025	P3
Interviews (6)	Identification of projects within the case	FCC, MCA + prefabricated products producer, real estate developer, 2 construction management consultants	Approx. 15 min each. Sept 22 – Oct 22.	P1
Interviews (27)	Identification of links between actors and motivators for IE engagement	CLTA, FCB, MCA, MCB, SEA + 3 main contractors, 2 real estate developers, framing contractor, 2 construction management consultants	15–30 min each. Oct 22 – Dec 23	P1

Table continues on next page

Table 3 continued				
<i>Method and activity</i>	<i>Purpose</i>	<i>Organizations involved</i>	<i>Duration</i>	<i>Papers</i>
Focus groups (11)	Content validation of dynamic capabilities	67 participants from 39 organizations within timber construction	30 min seminar + 45 min focus groups Dec 22	P2
Semi-structured interviews (9)	In-depth knowledge of strategies, practices and interactions within the network.	FCA, FCB, PrefabB, CLTA, CLTB, IP, AA, AB, REA	Approx. 45 min each. Dec 22 – July 24	P2, P3
Semi-structured group interviews (2)	In-depth knowledge on strategies, practices and interactions within the network.	MCB, FP	Approx. 45 min each. Dec 22 – July 24	P2, P3
Semi-structured interviews (6)	Creating a retrospective narrative of events, validation	FCC, PrefabB, Ass, timber construction promoting organization, CLTA, MC1	15-75 min Apr 25-Mar 26	P3
Public documents (22)	Creating a retrospective narrative of events, validation	FCA, CLTA, CLTB, PrefabA, BPOB, trade association	2025 - Mar 2026	P3

*Participatory observations*

During the exploration phase of the research problem and the development of the research design (2020–2021), I worked part-time with sales and early-stage design and planning of CLT-based building projects. This enabled in-depth participatory observation, primarily conducted through reflective engagement with the research problem alongside day-to-day work, allowing observation of how it manifested across different project settings. Such involvement provided important input to the development of research design. However, participatory observation may entail ethical challenges, including unintentional overexposure to sensitive information (Kawulich, 2005). To mitigate this, observations were used to inform the research design and to validate subsequent data collection, rather than as a direct source of empirical evidence. Consequently, no direct quotations or otherwise identifiable information from these observations have been included in the published work.

Additionally, in parallel with the participatory observations, I also conducted a separate pre-study, involving interviews with multiple stakeholders across five CLT-based building projects. The aim was to identify and trace key performance indicators related to resource use in design and construction with CLT. The interviews informed the development of a process map for CLT-based projects, which provided an initial, albeit limited, outline of the roles that a potential IE in CLT-based construction could encompass. The process-mapping activity also contributed to establishing a shared contextual understanding of CLT-based construction among the interview participants.

The involvement in bidding processes for CLT-based projects provided me with exposure to a wide range of project types. This typically, involved analyzing architectural and/or structural drawings, procurement documents and related information such as time schedules, life cycle assessment, environmental requirements and logistics constraints. I would also discuss these procurement materials with structural engineers, production managers and assembly managers, depending on the scope of the anticipated project deliveries. Such interactions provided near comprehensive coverage of all CLT-based projects planned in the case region, as well as insights into projects in other parts of the country during the same period. This contributed to my understanding of discrepancies between customers' expectations, the technical documentation and established 'best practices' among CLT-producers and framing contractors. These insights were subsequently valuable for analyzing and discussing IE alignment, incentives and the distribution of value capture among IE actors.

### *Seminar observations*

In the case region, two business promoting organizations (BPOA/B) actively supported timber construction companies in innovation and networking through organizing innovation projects and knowledge dissemination seminars. I have conducted this industrial doctoral work while employed by BPOA, which provided a company-neutral platform for the research and access to approximately 100 member organizations operating within sustainable built environment. BPOB has a more specific focus on timber-based solutions. These two organizations collaborate in timber-based construction activities and projects related to timber construction.

Two seminars were included as observations in the study. One was organized by BPOB in collaboration with three IE companies (CLTA, FCA, MP), aiming to disseminate knowledge on the co-innovation related to development, testing and factory pre-assembly of moisture membranes. The seminar was held outside the case region to reach a broader audience and the larger construction market in the Stockholm area. Each company presented its perspective on both the co-innovated solution and the development process, followed by a question-and-answer session with the audience. This seminar was recorded and transcribed.

The second seminar was organized by BPOA as a public focus group discussion, facilitated by me, as part of a larger regional business networking event. Four organizations within the IE were gathered to discuss both the co-innovation project of the previous seminar and broader issues related to collaboration and innovation prerequisites in the case region. This session concluded with a question-and-answer segment involving the audience. The main discussions and conclusions were documented in an online article published by BPOA, supplemented by observation notes.

### *Observations*

Throughout of the doctoral research, I continuously observed activities and interactions among the IE actors. I maintained regular communication with managers from FCA, PrefabA, PrefabB, SEA, Ass and MP, providing updates on building projects, co-innovation activities and organizational developments. In addition, I participated a launch event for one of the co-innovated products organized by SEA, as well as events hosted by BPOA. Relevant information was documented in observation notes and subsequently used to guide further data collection, including interviews and document searches.

### *Interviews*

During the study, four rounds of interviews were conducted, totaling 50 interviews, using different interview techniques and serving distinct purposes. To enhance quality and reduce bias, several measures were implemented, including triangulation across respondents and data sources, member checking, audit trails, and piloting to ensure construct validity (Roulston, 2010). Informants were selected based on their centrality to their companies' operational strategies for developing CLT-based construction, typically as senior managers or employees with significant operational responsibility.

Interviews were conducted by me, occasionally with the support by one co-author, and supervisor, to ensure quality and reduce bias (denoted 'member checking' by Roulston, 2010). The co-author's role was to observe the interview, which I led following the predefined interview protocol, and to raise clarifying questions at the end. After each session, a debriefing was conducted to align interpretations of the responses and to refine the interview approach.

Initially, two sets of shorter, structured interviews, primarily conducted by telephone, were carried out to delineate potential IEs. The first set provided information to identify relevant projects to include in the study, while the second set of interviews examined the company linkages within the selected projects. Due to the focused nature of these interviews, responses were documented in a Microsoft excel spreadsheet, compiling all projects and company linkages, along with notes on the informant and date of information, and validation of previous informants' information.

The third round of interviews consisted of semi-structured interviews aimed at obtaining in-depth insights into companies' strategies, practices and interactions within the network. These interviews were primarily conducted via Microsoft Teams and were recorded and transcribed. A set of seven main interview questions was developed prior to the interviews, along with predefined follow-up questions to ask to clarify responses and explore emerging topics. The interview questions were slightly adapted to suit different organizational roles. During the interviews, additional unprepared follow-up questions were asked. My prior familiarity with the case context, gained through observations and previous professional experience, enabled me to focus on the core research topics and thereby minimizing time spent on contextual clarification during the interview sessions.

The final round of interviews was also semi-structured, however, in contrast to the earlier interviews, they adopted a narrative approach (Langley, 1999).

Informants were asked to describe, in chronological order, the events that had shaped the IE companies, their collaborations, and their co-innovation activities. Once the narrative reached sufficient saturation at the selected level of detail, an additional validation interview was conducted with an informant possessing broad knowledge of the companies' trajectories within the IE. Following this, and in combination with the documentary data, the narrative was finalized.

### *Focus groups*

As DC theory is not widely known outside the academia, the data collection was framed in terms of companies' practices and strategies. To ensure traceability to DC theory and content validity of identified practices, a large focus group exercise was conducted early in the doctoral study. Drawing on DC and IE theory (Adner & Kapoor, 2010; Adner, 2016; Linde et al., 2021; Teece, 2007), a comprehensive set of potential microfoundations (Teece, 2007) for DCs relevant to CLT-based construction was identified, and further refined through collaborative analysis by all three co-authors of P2, resulting in a final set of 21 potential microfoundations. These were organized into 11 subsets of three, with some microfoundations appearing in more than one subset, which were discussed in 11 focus groups during a seminar day arranged by BPOB on industrialized timber construction.

The participants were assigned into groups prior to the event to ensure balanced compositions, and each group had an assigned chairperson responsible for taking notes and reporting the results. Discussions were guided around three predefined questions addressing meaning, industry examples and challenges versus opportunities. Input from the focus groups both validated the identified microfoundations and provided additional contextual insights. The outcomes from the focus groups informed the development of the seven interview questions (see P2) for the semi-structured interviews conducted in the third round.

### *Document search*

To support the longitudinal analysis in P3, following principles outlined by Langley et al. (2013), public documents communicating strategic decisions related to the network and/or the co-innovations were collected. The company websites, corporate LinkedIn profiles, and press releases of five IE actors were screened in full and reviewed. Notably, LinkedIn feeds are only visible for the previous 12 months, which limited this search.

18 documents from CLTA, CLTB, FCA, PrefabA, BPOB as well as two newspaper articles, a national policy document for sustainable construction, and a report on national statistics on construction were included in the analysis, totaling 22 documents. Corporate documents and newspaper articles were selected based on their focus on co-innovation and company collaborations, while the additional two reports were included to validate interviews.

### *Analysis*

Different qualitative analysis methods were applied across the three papers, each selected to address respective research questions. As the datasets accumulated continuously and were reused across papers (Table 3) the use of multiple methods for analysis enabled iterative reflection on the same empirical material from different theoretical perspectives.

In P1, a structure for IEs in CLT-based construction was established by mapping collaboration networks among companies, consisting of two competing, partly overlapping IEs within the case region. The analysis focused on identifying bilateral, contractual and information links between actors in 15 CLT-based building projects. To achieve this, social network analysis (Scott & Carrington, 2023) was applied in combination with a method for structurally identifying potential innovation ecosystems within the construction industry.

The analysis showed that some companies were more frequently involved in the CLT-projects than others within the same role (e.g., structural engineers, CLT-producers, framing subcontractors), and it also revealed that certain companies appeared to act as key partners in two competing IEs. While this approach enabled systematic categorization of supply chains, it also carries the risk of overinterpretation bias stemming from the method's reliance on predefined IE criteria.

In P2, the aim was to investigate how DCs support CLT-based co-innovation within and across building projects. To operationalize DCs, the study focused on observable activities indicative of such capabilities, in line with the microfoundational perspective proposed by Teece (2007). The critique regarding applicability of DC theory in construction research (Green et al., 2008) was addressed by shifting the analytical focus from abstract capabilities to concrete activities. The data was here analyzed by using reflexive thematic analysis (Braun & Clarke, 2006; 2021), which provides a structured approach for developing themes while allowing the researchers' own contextual knowledge to inform the

analysis. This approach was well suited to make use of my prior knowledge of the case context and activities in an academically encouraged manner. This approach to thematic analysis allows the researchers to develop meaning and patterns of data, in contrast to finding patterns by frequency. Accordingly, the risk of bias is apparent when using this approach, which needs to be balanced to the benefits.

P3 adopted a longitudinal design, examining how the IE organizing evolved over a period from 2013–2025, framed by IE life cycle theory. The data were analyzed as process data following methodological guidance by Langley (1999) and Langley et al. (2013), with events representing key developments within the IE. Prior to, and in parallel with, extracting process data, a narrative was developed to describe the evolution over time. This narrative approach (Langley, 1999) was applied in the additional interviews conducted for P3, iteratively developed and validated until sufficient saturation was reached.

A chronological visual map of events was created to display IE development and interrelated events, with temporal bracketing applied to delineate four IE lifecycle stages. While these methods enabled tools for visualizing and synthesizing complex developments, limitations in generalization arise from the single-case design and the selected case boundary, which centers on the framing contractor as the focal firm. In the discussion of P3, alternative analytical perspectives were therefore acknowledged, suggesting that different insights might emerge if the IE were analyzed from the perspective of a different focal actor, such as a CLT producer.

### *Ensuring reliable research*

Throughout the doctoral work, I have developed my own perspectives on reality, knowledge and research. My ontological position of reality is still the same as before, aligned with critical realism where I recognize that we see and interpret only what we have tools and knowledge available for. However, I have been challenged to explain and contextualize it to research, and also to understand how my view of reality influences my understanding of others' research. I assume that the world is more complex than we can fully observe and that our understanding is shaped by previous knowledge, values and, in the case of research, theoretical foundations, to shape our understanding of reality. As we translate observations through these lenses, whether deliberate or undeliberate, we need to remain aware of how they influence the analyses drawn from those observations.

In this research, I have examined company collaborations through an IE lens, in conjunction with my own lived experience from holding various roles of the studied IE. Consequently, the findings and conclusions reflect these prerequisites. Another researcher examining the same empirical setting might arrive at another story, yet equally valid, just from a different perspective. The purpose of this research is therefore to contribute to learning by offering one such perspective, and I hope that this research, combined with other research and experiences, stimulates further reflection, learning and future studies on co-innovation and its commercialization in the construction industry.

This thesis builds on an extensive dataset that I have been able to access partly through my own prior professional experience in CLT-based construction, including both knowledge and relationships with multiple organizations and professionals within the field ranging back to 2015, when the first CLT-based buildings were planned and built in the region. Prior to starting the doctoral work, the research questions started to emerge as I observed the CLT-industry's challenges in optimizing and aligning the products to a broader system and in achieving efficiency when applying mass production principles in a fragmented construction context.

Later, the doctoral work was hosted by the regional business supporting organization Byggdialog Dalarna, providing access to around 100 member organizations and associated networks. While industrial doctoral projects inherently involve closer researcher-industry ties, potentially increasing the risk of bias as discussed earlier, they also enable deeper empirical insight, a balance that requires active management.

Personal involvement in the empirical setting proved valuable for data collection, analysis, and recruiting interviewees, reflected in a 100% interview acceptance rate throughout the study. However, this involvement also introduced potential bias risks, which were continually discussed and managed through bi-weekly supervisory meetings across the doctoral process. During interviews, particular caution was required to avoid influencing informants' responses; instead, my contextual understanding was focused on clarifying follow-up questions to deepen the data.

Bias was further mitigated through several measures. Analysis was generally conducted by all three authors independently, then discussed and finalized in group sessions. My co-authors were not immersed in the data and as I was, and through this approach we could mitigate my bias associated with pre-existing knowledge and industry relations. Interview questions for the semi-structured interviews in interview round three were developed and validated through focus

groups and independent co-author review prior to the interviews, as piloting activities (Roulston, 2010). In addition, one of my supervisors regularly joined interview sessions, followed by a debriefing session to discuss interview technique, refine interview questions and harmonize our shared understanding of the answers, as a form of ‘member checking’ as advocated by Roulston (2010).

Beyond researcher triangulation through independent analyses, data were validated through multiple data collection methods and sources across all papers (Eisenhardt, 1989). P3 employed a longitudinal approach tracing IE activities back to 2013, predating the doctoral work, and combining real-time and retrospective data. As noted by Langley (1999), these data types differ in richness and reliability, with retrospective accounts potentially influenced by memory and subsequent events. To mitigate this, documentary data sources and observations were used for validation, while acknowledging temporal bias of the observations.

At the thesis level, the multi-method design combining three distinct approaches in each paper provides methodological triangulation, where the research questions are analyzed through a synthesis of findings across all three studies.

During the thesis work, AI tools became publicly available. In this thesis, and appended papers 2 and 3, two services have been used solely for language-related support, including spelling, grammar, and stylistic clarity: Microsoft 365 Co-pilot (ChatGPT model 5.0 with enterprise data protection) in P2 and P3, and Claude (Anthropic, 2025) in this thesis. The tools were not used to generate original scholarly content. All substantive ideas, arguments, and interpretations included are entirely our own. Co-authors have reviewed and verified all text material to ensure accuracy and integrity.

### *Generalizability of the single-case study*

As the thesis, and the appended papers (P1-P3) adopt a single-case study design, generalization is analytical rather than statistical (Yin, 2018). The primary approach was to develop existing theories on IEs and DCs within the context of CLT-based construction, with potential relevance to broader project-based construction settings, though further validation through additional studies within similar contexts is needed.

The research is exploratory, seeking to generate empirical insights rather than establishing causal relationships. Visual mapping and temporal bracketing are considered high on accuracy for generating novel insights though limited in

generalizability (Langley, 1999). Temporal approaches are particularly suitable for studying organizations, as statistical methods tend to reduce organizational choices and events to a discrete point in time, overlooking the influence of continuously evolving internal and external conditions (Langley et al., 2013). Patterns or causal relationships identified through such methods may therefore not be readily transferred across contexts or time periods. By adopting a temporal and qualitative approach, this study aims to generate insights and learning that remain actionable across varying conditions.

The studied phenomenon, CLT-based construction, is closely related to construction using other engineered wood products (EWPs), such as glue laminated timber, laminated veneer lumber, and hybrid timber-based structural components, which are often integrated as complementary components into the building systems of CLT-based construction, but can also serve as the primary load-bearing material in alternative building systems. The findings may therefore be analytically transferable to other EWP-based construction contexts and, more broadly, to other subsystems within the construction industry, given similarities in supply chain structures and the systemic nature of their value propositions.

However, caution is required when extending the findings across regions or networks, even within CLT-based construction, as some results may be contingent on specific actor interactions during the studied period. That said, the discussion aggregates findings to a level beyond the studied networks, developing a proposition for hybrid integration through IEs in relation to other common construction management principles, thereby seeking theoretical generalization beyond the immediate case context.

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## SUMMARY OF APPENDED PAPERS

*The three appended papers examine various aspects of IE collaboration within CLT-based construction. Firstly, P1 identified and characterized two potential IEs from a larger set of CLT-based projects, distinguished by their systemic approach on a shared value proposition. The second paper, P2, investigated how the two IEs operate by analyzing activities through a dynamic capabilities' lens. Lastly, P3 traced organizational developments of one of the IEs in relation to co-innovation, value capture and investments to describe how the IE operations developed over its lifecycle. An overview of each paper's contribution to the four research questions is found in Table 1 and further elaborated in this chapter.*

### *P1: Innovation ecosystems beyond construction projects—a case study of Swedish cross-laminated timber building networks*

This study aimed at identifying and describing IEs in CLT-based construction. By analyzing data on linkages between supply chain actors in 15 CLT-based building projects in mid Sweden, two potential and partially overlapping IEs were identified. The study presented evidence on collaborative continuity within these IEs around a shared value proposition of a *project optimized installed CLT framing* across multiple building projects (RQ2). In contrast to IE theory, where actors are expected to hold specific and collectively agreed roles and positions

within the IE, the study revealed occasional role extensions by actors, enacted as one actor temporarily assuming the role of another actor (e.g., a main contractor assuming the role of framing contractor, or a CLT-producer adding technical services to its delivery), assumingly a consequence of prevailing construction industry dynamics. The findings also highlighted the IE as a superimposed structure on the individual building project structures (RQ3). The importance of additional value capture as motivator for such collaboration was further discussed, distinguishing expected value capture from project deliveries and from the IE collaboration more broadly (RQ1). Furthermore, the findings revealed alignment links between actors, that were not necessarily contractually tied to each other, indicating collaboration extending beyond project deliveries and provided the basis for the subsequent P2. The paper provided a foundational framing of the structure and motivators for interorganizational collaboration on a systemic value proposition for CLT-based construction across building projects.

*P2: Dynamic capabilities for co-innovation in timber construction: a case study of Swedish cross-laminated timber innovation ecosystems*

The aim of this paper was to investigate how capabilities supporting co-innovation and value capture develop across multiple building projects. The case selection built on the two IEs and the projects identified in P1, complemented by further data collection to capture practices indicative of dynamic capabilities. While P1 first identified cross-project collaboration through analyzing contractual and alignment links between actors, this study developed a deeper understanding on the practices enacted across projects, focusing on how co-innovation and value capture were operationalized in practice.

Findings show that the shared value proposition is central to both co-innovation and value capture. Co-innovation centered on developing processes, services and products that enhanced the shared value proposition; however, an important finding is that the co-innovated products need to remain open for commercialization beyond the IE and its shared value proposition. This corroborates the importance of capability development, as the products themselves were not unique for the IE and the competitiveness appeared to stem from shared capabilities developed as the collaboration matured. IE-related value was captured in several ways, including efficiency benefits from scaling through

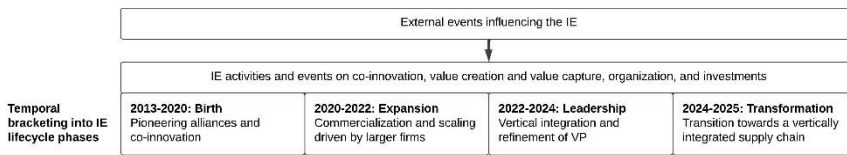
consistent delivery of the shared value proposition, shared resources for innovation, and knowledge dissemination. The focus on value capture in this paper provided enacted insights into the motivators for cross-project collaboration (RQ1), elaborating on the expected value capture recognized in (P1).

The findings suggested three levels of capabilities (RQ4): level 1 operational capabilities, focusing on adjusting and delivering the shared value proposition in projects, level 2 dynamic capabilities that involve co-innovation and development of shared routines and financial actor incentives, and level 3 dynamic capabilities, developing the collaborative structures through actor and role alignment, and establishing routines for knowledge sharing and learning. These three levels can be described as interconnected and dependent on the enacted practices (Figure 2Figure ) While capabilities were identified through activities enacted at the company level, they appeared to be partly collaboratively developed within the IE around the shared value proposition. Leadership seemed distributed across actors rather than governed centrally by the focal actor. This points to the IE as a flexible interorganizational form in which collaborating firms can develop and capture value from systemic innovations.

### *P3: Temporal dynamics of a CLT-based innovation ecosystem: Organizing for co-innovation and value capture over time*

This paper examined the evolution of IE organizing in a temporal manner, by studying organizational changes in relation to co-innovation, value capture and investments within the IE across a period of 13 years. The role extensions observed in P1 were traced over a longer period and strategic organizational changes were observed in addition to temporary role extensions. Four IE lifecycle phases were observed: birth, establishment, leadership and transformation, exhibiting a trajectory from early co-innovation and exploration of CLT-based construction by smaller pioneering companies, through commercialization of a shared value proposition and entrance of larger actors into the IE, towards consolidating suppliers by vertical integration and a strong focus on value capture (Figure 5). By the end of the period, a part of the IE had been transformed into a vertically integrated supply chain for CLT-based construction (RQ3), controlled by a large main contractor. Producers of mass-market products, such

as CLT, glue laminated timber, and membranes were operating as independent organizations throughout the lifecycle. This implies the IE could be operationalized as a risk-mitigating network for early systemic co-innovation in CLT-based construction, before investments in vertical integration for securing long-term value capture are considered. The study also highlights the importance of innovative building projects for stimulating co-innovation and investments, and their role for testing and implementing innovations. The projects, combined with the IE collaboration, seemed to provide an arena for co-innovation both for the consolidated group of companies and for organizationally independent suppliers of products that are commercialized outside the IE.



*Figure 5. Temporal bracketing of IE activities and events into four lifecycle phases (simplified from P3).*

## DISCUSSION

*This section starts by discussing the findings through the lens of construction industry characteristics, providing a general contextual framing of the CLT-based construction IE. It then addresses the four research questions and their corresponding answers and finally elaborates on the findings in a broader context, positioning IEs as a potential hybrid solution for industrialized building within conventional on-site building projects.*

### *Fragmentation, standardization, projects and long product life cycles influencing IE boundaries*

IE theory appears to provide a suitable lens for analyzing how specialized companies mobilize resources for continuous systemic co-innovation within CLT-based construction, though the theory needs contextual adaptation. The construction industry remains fragmented, comprising a multitude of specialized companies of varying sizes within different positions in the value chain (Hughes & Stehn, 2019). At the same time, processes and products are heavily standardized to fit the overarching system, i.e., the building itself, (Dubois & Gadde, 2002) and comply with building regulations, resulting in long product life cycles. Furthermore, customer value is created in projects rather than through continuous production. Together, these industry characteristics have significant implications for how IE theory could be applied to CLT-based construction:

### *Long product life cycles and projects*

As the objective of an IE is to develop and maintain a focal value proposition (Adner, 2016), long product life cycles would reduce the need for continuous co-innovation once the focal value proposition is established on the market. Adner (2016) describes that a member of the IE becomes obsolete when its individual value proposition no longer requires adaptation. However, since every building project is unique, many, though not all, of the ingoing individual components constituting the focal value proposition need to be adapted to the project. CLT is such a component, which calls for CLT-producers to be continuously aligned with the IE. This means that even though the main component CLT remains stable, its processing for projects is ever-changing. However, when project adaptation is efficiently managed, it can be executed by routinized operational capabilities developed within the IE (P2) and should thus not be considered development or innovation work (Winter, 2003). At a point when both multilateral capability development and the development of activities or products related to the focal value proposition slow down, the IE would, according to Adner's (2016) principles, become latent and would likely, at least temporarily, be replaced with traditional bi-lateral business relationships. This capability-perspective on IE operations treats the building project as business-as-usual, while recognizing that projects also serve as arenas for more directed innovation activities within the IE (as explicitly studied by Poblete et al., 2022). This contrasts with existing contextualization of ecosystems in construction industry, which apply the building project as boundary of the ecosystem (Vigren, 2024).

### *Fragmentation*

A single focal firm typically lacks the capacity to match the scaling needs of large industrial producers, such as CLT-producers. Consequently, products and solutions co-innovated within the IE need to be allowed for marketing beyond the focal firm to a broader construction market (P2 & P3). This may pose challenges in terms of internal competition as a product supplier may be bidding for the same project through multiple collaborations or even directly to the main contractor, thereby bypassing the IE VP. Conflicts stemming from such competition were observed in the study (P2 & P3), but these could predominantly be managed within the IE.

The non-exclusiveness of products and solutions within the IE would, according to the findings in P2, require the focal firm to actively develop

collaborative dynamic capabilities to sustain actor engagement following co-innovation, particularly among larger IE companies such as CLT-producers. Such engagement may be strengthened by ensuring that IE actors capture more value from IE-based collaboration than through individual business opportunities (P2), consistent with previous researchers' cautions regarding the importance of managing mechanisms for value capture (e.g., Adner, 2016; Ben Letaifa, 2014; Ritala et al., 2018).

In addition to industry fragmentation, fragmentation within building projects influences the IE and its VP. In building projects, processes are divided through clearly defined contracts among various actors, imposing discontinuities in cross-actor collaboration (Hughes & Stehn, 2019). As the IE boundary includes upstream complementors, such as architects or consultants providing technical advice in early stages of the project process, these influence the IE VP boundaries before the IE is engaged. Since this work occurs outside the IEs influence, actors independently and collaboratively pursued proactive learning and alignment activities directed towards these groups of complementors, as well as the IEs potential customers, aiming to align requests for proposals toward CLT-based construction (P1). Downstream complementors providing products integrated into the CLT structure after assembly, such as insulation systems or fire protection products, influence the overall efficiency of CLT-based construction. Including these actors in co-innovation and IE alignment would be beneficial; however, such activities were absent according to the findings in P2.

Longitudinal fragmentation, causing discontinuities across building projects, seemed to be successfully managed within the IE boundary by the IE actors developing capabilities for resource optimization, co-innovation and learning, drawing on the scaling effects of the sustained partnerships (P2).

### *Standardization*

As individual components are also intended for the broader construction market (P2), they must be compatible with standardized processes and systems, and legislation across the industry (Dubois & Gadde, 2002). At the same time, system boundaries of the focal value proposition must align with these standardized interfaces. However, the interconnectedness between components and companies within the realization of the focal value proposition may be specialized beyond construction standardization, creating interdependencies that could generate competitive advantage within the IE, but would simultaneously introduce barriers to market scalability for individual components. Such deviation

## CONCLUSIONS

from industry standards may increase risk exposure for IE companies: if new products only fit within a unique IE value proposition, investments in development and innovation need to be balanced against the potential volume and profits of IE business. This risk can be mitigated by instead developing unique IE capabilities that integrate specialized practices within the boundaries of IE value creation, thereby reducing the investment cost associated with off-standard specialization while preserving IE competitiveness.

The IE may serve as a means to explore IHB solutions, with a consolidation to a larger industrial platform once innovations have been proven viable. New development projects could then be initiated as IEs when there is a need to develop and test platform innovations in a risk-mitigated manner, making IE theory promising for this context as it provides a framework for governing collaborative innovation that is both temporary and scalable, without requiring full vertical integration. This approach combines long-term value capture from innovations, responding to the expectation of long product life cycles, with the temporary integration of external resources from specialized suppliers in the fragmented construction industry. When dynamic capabilities for leveraging IE collaboration have been developed, IE practices can potentially be applied as demand-driven, partly external, co-innovation operations.

### *Answering the research questions*

The overarching research question of this thesis was:

*How can company collaborations in CLT-based construction be organized to support co-innovation and its implementation across projects?*

Based upon the findings in this study, and its theoretical discussion, the IE structure appears promising for sustained co-innovation in the slow-moving construction industry when combined with collaboratively developed dynamic capabilities and integrated with mechanisms for testing and development in building projects.

*RQ1: What are the motivators for co-innovation for companies within CLT-based construction?*

The primary motivator for IE participation appears to be increased value capture through improved efficiency from continuity and scaling principles, co-innovation, and shared sales and resources (P2). This can be realized through the operational structure of the IE, supported by capabilities in negotiating and distributing value capture. Such an approach avoids opportunistic contract-based bargaining one project at a time.

For implementation across projects, the findings indicate a dual strategy for value capture: continuous business collaboration through the focal value proposition within the IE combined with individual companies' delivery of developed components to projects outside the IE collaboration. The findings further suggest that the possibility of sharing early innovation risk and resources with external partners constitutes a significant motivator for co-innovation, particularly when integrated with mechanisms for testing and development in building projects.

*Companies engaged in CLT-based construction appear to be motivated to participate in co-innovation primarily by the prospect of increased value capture through shared resources, scaling effects, and risk distribution, enabled by a collaborative IE structure that ensures continuity across projects.*

*RQ2: What determines the boundaries for co-innovation in CLT-based construction?*

The boundaries for co-innovation are partly shaped by the IE VP, which defines the scope for co-innovation in line with existing IE theory. However, findings across the three papers also indicate that some actors approach the IE with their own agenda for developing products for a broader market, thereby contributing to the development of the focal VP from an outside-in perspective. These dual logics are further constrained by industry demands for standardized product and process interfaces, which delimit the scope of co-innovation from the outside. P2 further reveals a predominance of supplier- and focal firm-initiated co-innovation processes, with complementors' initiatives remaining largely absent. Furthermore, while co-innovation may be oriented around the shared VP, P3 in particular highlights the role of building projects with innovative requirements for shaping co-innovation. Such projects appear to stimulate not only IE emergence but also refinement of the shared VP and the introduction of new partners to the IE,

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suggesting that the boundaries of co-innovation are subject to a balanced push-pull dynamic between internal IE development and external project demands. Findings in P2 further suggest that dynamic capabilities supporting co-innovation and implementation in building projects contribute to this process.

*The boundaries for co-innovation in CLT-based construction appear to be determined by a combination of the shared value proposition, industry standardization, and external project requirements, and supported by dynamic capabilities.*

*RQ3: How can the collaboration be structured and managed over time?*

RQ3 is primarily addressed through P3, supported by insights from P1 and P2, drawing on data gathered across the full thesis including retrospective data extending the studied time period. The findings trace early collaboration initiatives driven by smaller actors and their involvement in innovative building project contracts, exhibiting a trajectory of risk-sharing in early stages of innovation. As the shared VP became established on the market, larger actors' involvement in the collaboration increased, followed by a phase of investments in vertical integration and a subsequent consolidation of the new resources into the focal actor's organization. This is consistent with Adner & Kapoor (2010) on the benefits of vertical integration as technologies mature, and reflects strategic investments for securing long-term value capture of established products, corresponding to the expected long product life cycles characteristic of the construction industry. The findings thus indicate that IE structure represents a viable path for developing industrialized solutions prior to committing to investments in vertical integration. Moreover, capabilities for co-innovation may still be relevant when established CLT-based construction solutions need further adjustment.

*Collaboration within the studied IE in CLT-based construction evolved from early risk-sharing and exploration among smaller actors toward vertical integration as the shared VP matured. This suggests that the IE functions as a transitional structure prior to more permanent organizational commitments.*

*RQ4: What capabilities can be developed by companies to benefit from collaboration?*

RQ4 was explicitly investigated in P2 through actor activities, with traces of these activities observed across the whole study. Activities oriented toward integrating IE actors' resources into a shared VP were identified, alongside the development of new routines for capturing value of co-innovated solutions and accessing efficiency benefits and learning from the continuity of business relationships across multiple building projects. Previous research on DCs within IEs emphasize the importance of strong leadership capabilities held by IE leaders (e.g. Foss et al., 2023; Helfat & Raubitschek, 2018; Linde et al., 2021). The activities observed in this study instead illustrated a decentralized leadership structure (Dedehayir et al., 2018), in which actors shared the responsibility for initiating co-innovation, developing the VP, and gathering actors in learning activities. As discussed under RQ2, co-innovations were aimed at a broader market than the projects delivered through IE collaboration, indicating that capability development is vital for achieving additional value capture through IE-delivered building projects and for maintaining IE competitiveness. With reference to the discussion under RQ3, the IE developments in P3 indicated a transformation into a partially vertically integrated supply chain, suggesting that capabilities for co-innovation may remain beneficial for the continued development of the building system.

*The alignment of the CLT-based construction IE appeared to be orchestrated through DCs exercising decentralized leadership. Development and operations of the IE rely on DCs oriented both toward co-innovation beyond the shared value proposition and toward capturing value from sustained partnerships.*

## *Hybrid industrialized house building through networks*

In this thesis, the networked activities in co-innovation and commercialization of CLT-based construction have been discussed in relation to construction industry characteristics such as project logic, fragmentation, standardization and long product life cycles. Other ways of approaching the same contextual characteristics are through construction management mechanisms (e.g., contracts management (Bygballe et al., 2016; Dubois & Gadde, 2002; Eriksson, 2015) and project team integration (Hall et al., 2018)) in conventional on-site construction, and control

## CONCLUSIONS

of supply chains and product platforms in industrialized house building (e.g., Lessing et al., 2015; Lessing & Brege, 2018; Stehn et al., 2021). From a CLT-based construction perspective, the discontinuity across projects in traditional construction management procedures complicates development and implementation of optimized CLT-based building systems.

The building system-based IHB approach is designed for project continuity, but on the other hand focused on off-site modular designs that have been rather successful in their aim at niched market segments (Lessing & Brege, 2018). This specialization and prefabrication have been shown to increase productivity (Stehn & Jimenez, 2023) but is dependent on investments in production and vertical integration that increase the risk for reduced flexibility caused by path dependency at the focal actor. The modularity, designed for efficient road transportation, limits the sizes and application of CLT-panels. This delimitation is consequently not utilizing the full structural benefits of large CLT-panels for large building projects, as advocated by Ilgin et al. (2023b), and needed for a market-wide transition to low-carbon construction materials (UNECE/FAO, 2021).

Table 4 presents a generalized comparison of these three organizational approaches, mirroring dimensions for innovation development and implementation that have been studied in the thesis. Overall, the operational characteristics are distributed along an axis from conventional short-term collaborations in one-off, flexible building projects allowing unlimited variations in building types and geometrics to IHB long-term collaborations based on vertical integration and platforms aiming at repetition of similar buildings across projects (Figure 6). The IE is here situated in between, as a hybrid, networked alternative to traditional on-site construction or IHB. The IE approach could therefore enable 'industrialization light', where certain aspects of IHB (building system development, continuity and learning, scaling benefits) may be accessed by a network of companies while operating in the flexible and larger market of on-site construction.

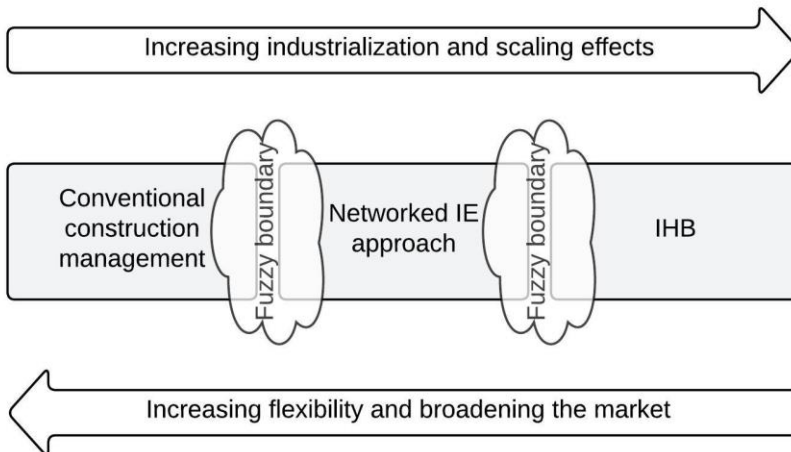
Table 4. Comparison between conventional on-site building, IE collaboration, and IHB across dimensions relevant for innovation and its implementation.

Dimensions	Conventional construction management	Innovation ecosystem	Industrialized house building
<b>Innovation</b>	Executed by temporary organizations within individual projects to meet project-specific requirements	Executed by interdependent actors within the IE within, and between individual projects, motivated by project requirements, actors' individual long-term goals and a shared goal of improving the shared VP	Managed within the organization and its supply chain, owned by the focal firm. Aimed at developing the product platform.
<b>Learning</b>	Ad-hoc, within projects, low knowledge transfer between projects	Semi-structured knowledge transfer between actors and projects	Structured, process driven. Integrated into product platform.
<b>Value propositions</b>	Standardized components, integrated into unique systemic VPs (buildings)	Standardized components integrated into a semi-standardized systemic VP (sub-system or building)	Standardized components integrated into a standardized systemic VP (building)
<b>Organization</b>	Temporary, project-based supply chain	Firm collaborations between building projects, temporary building project teams formed of subsets of the collaborating firms	Vertically integrated combined with long-term suppliers
<b>Contractual agreements within supply chain</b>	Project-based	Project based, supported by long-term contracts	Long-term contracts
<b>Value capture</b>	Distributed within building projects through contracts	Distributed within building projects through contracts, additional efficiency benefits from scaling principles and resource sharing realized through shared capabilities within the long-term collaboration	Centralized within building projects. Efficiency benefits from large-scale implementation of product platform.

This study also opens an additional possible development: the IE collaboration as a transitional pathway from conventional construction management toward IHB.

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This could encompass company collaboration for co-innovation and early implementation, with a later change of strategy towards vertical integration and development of IHB practices and more comprehensive product platforms. In this scenario, capabilities developed through IE collaboration may remain relevant for the focal company as a means to initiate spin-off development projects aimed at extending the platform. With this said, the categorization presented in Table 4 should not be seen as definitive, but as a continuum (Figure 6) from which companies may develop individual strategies in relation to their long-term objectives and prioritizations. The IE approach could thus be a networked alternative for traditional construction companies seeking to explore the possibilities within industrialization.



*Figure 6. Three operational approaches in construction industry in a continuum.*

## *Methodological discussion*

A strength of this thesis is the rich empirical material collected across the three papers, drawing on data from multiple organizations within the selected region, combined with prior professional experience and participatory observations. However, the regional boundary limits generalization, as the findings should be considered most directly applicable to this network, region, and time period. This reflects a trade-off between in-depth knowledge and generalizability (Yin, 2018) that was considered in the study design and motivated by the critical case strategy (Flyvbjerg, 2006).

A further strength lies in analyzing the data through different methodological approaches across the three papers, each selected for its suitability to the respective research questions. The synthesized findings are thus methodologically triangulated (Jack & Raturi, 2006), as data aggregated across papers were reanalyzed through different methods and research questions, all contributing to the thesis research question.

A limitation of the overall thesis design is that its exploratory nature meant research questions were developed sequentially as the study progressed, making it impossible to design a data collection strategy with full alignment across all three papers from the outset. Some data were consequently collected for one purpose but subsequently reanalyzed in a later paper. Had the full study design been established at the start, data collection could have been more precisely tailored to each paper, a limitation that was mitigated through complementary data collection conducted for each paper.



## CONCLUSIONS

*This final chapter summarizes the main findings of the thesis on the organizational and capability-driven development of CLT-based construction through co-innovation and a shared value proposition, and its possible implications for the development of industrialized practices. It further outlines the contributions to theory and practice and suggests areas for further research.*

This thesis departed from a need for collaborative structures for managing systemic innovation to develop and scale CLT-based construction across building projects. This has been examined in three empirical papers, successively building the data to cover structural links, motivators, capabilities and organizing among a network of collaborating companies in mid-Sweden. Data were analyzed through innovation ecosystem (IE) and dynamic capabilities (DC) theory using different methodological approaches across the three papers. Together, the papers contributed complementary perspectives on co-innovation in CLT-based construction IEs. These were synthesized in this thesis through describing the development of CLT-based construction as an IE, highlighting the specific contextual influence of project-based value creation, industry standardization, fragmentation and long product life cycles.

Expectations of increased value capture emerged as an important motivator for IE collaboration in general, and for engaging in co-innovation specifically. Co-innovation was centered around, but not exclusive to, the shared value proposition, delimited by industry standardization and triggered by external project demands. The studied IE underwent a development from early exploration and risk-sharing toward vertical integration in later stages. Activities underpinning IE-specific DCs for co-innovation and value capture were observed at both collaborative and individual actor levels.

## CONCLUSIONS

The studied IE collaboration was further positioned between conventional construction management and industrialized house building by relating it to flexibility of building types and market segments versus industrialization and scaling effects. The thesis provides a networked perspective on co-innovation and the development of CLT-based construction, approaching industrialization in conventional on-site building projects.

### *Contributions*

This thesis contributes to IE, IE lifecycle, and DC theory by empirical testing and development in a construction industry context. It develops IE lifecycle theory by its full lifecycle perspective, and with insights on the transitional period at the end of the lifecycle. All three papers involved methodological contributions, developing and testing methods for IE and DC research in construction industry, and testing longitudinal process methods for analyzing IE lifecycles.

The thesis contributes to IE theory by applying it within the project-based context of CLT-based construction and by developing existing research on IE lifecycles (e.g., Daymond et al., 2023; Moore, 1993) through providing empirical data and analysis that covers temporal developments of a full IE lifecycle, including its gradual dissolution when transforming into a vertically integrated supply chain (P3). The roles of upstream and downstream complementors in the building project context were highlighted, contextualizing and developing the discussion on complementarities in IE theory (e.g., Adner & Kapoor, 2010; Jacobides et al., 2018). It also develops the understanding of DCs in IEs, illustrating how collaborative DCs may be developed within an IE, as well as their role in IE co-innovation and corresponding value creation and value capture, extending beyond DCs developed and possessed by the leader (P2).

The thesis provides three methodological contributions: a method for identifying and describing IEs in construction, responding to the lack of ecosystem boundary coherence and methods for their delineation in construction management research (Vigren, 2024) (P1), a practice-based approach for tracing dynamic capabilities in construction industry, addressing the critique by Green et al. (2008) (P2), and testing visual mapping and temporal bracketing of process data for analyzing temporal developments within the IE, in response to Phillips & Ritala (2019) (P3).

The thesis further contributes to construction management research with a complementary perspective on managing co-innovation across multiple projects

through the IE approach, and introduces the IE as a possible pathway toward industrialized house building. These findings offer actionable insights into networked approaches for managers in construction industry seeking systemic innovative solutions, and for policymakers aiming at creating supportive environments for such developments.

### *Further research*

For broader applications to DC theory, further research could explore capabilities at a higher level of abstraction, examining the ecosystemic way of operating and how it draws on collaboratively developed capabilities that generate routines shared and integrated across organizational boundaries. Such research would add actionable perspectives for all IE actors, extending beyond the IE orchestrators activities and capabilities, and potentially developing the notion of shared leadership within IEs. Additionally, research could investigate how vertically integrated organizations in construction industry apply the IE approach and corresponding capabilities to extend and innovate their established platform, including the organizing and feasibility of such an arrangement. The mechanisms and drivers behind investment decisions in vertical integration could further be examined, deepening the understanding of the IE approach in CLT-based construction on why certain products and organizations become vertically integrated while others are sustained as IE interdependent partners. Furthermore, a feasibility-based study could address the effects of the IE on developments of CLT-based construction and their sustainability impact, investigating the IE as a networked co-innovation structure and its calculated potential for lowering the carbon footprint of construction industry, thereby extending this study's focus how sustainable co-innovation is managed to also include the potential effects of it.

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