Digital transformation in a cross-laminated timber business network

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Abstract

Purpose – The purpose of this paper is to investigate two current transformation processes in the construction industry: the adoption of a novel material, cross-laminated timber (CLT), and the enhancement of digital transformation. This paper depicts the actors and interaction in the business network that is emerging around CLT construction and, in particular, how digital transformation (that is, the deployment of Construction 4.0 solutions) occurs in this business network.

Design/methodology/approach – Digital transformation is a relatively new phenomenon in CLT construction, and the authors, therefore, adopt a qualitative inductive research approach and rely on semi-structured interviews.

Findings – The findings of this paper suggest that it is critical for actors to adopt an interorganizational perspective in CLT construction, instead of only focusing on internal operations. An interorganizational perspective supports successful CLT construction, as well as the deployment of Construction 4.0 solutions. This will bring about the benefits of digital transformation in the construction industry.

Research limitations/implications – This paper investigates the network created around CLT construction in Finland but more generally illustrates the change toward Construction 4.0 solutions.

Practical implications – For managers, this paper explicates the importance of networking, instead of focusing on the internal development of the company, when adopting novel solutions emerging from both construction and information technology-related advancements.

Originality/value – Stability and traditions are characteristic of the construction industry. New technical solutions and materials, together with calls for sustainability, have challenged the traditional ways of constructing, and for example, the development of CLT construction has led to an emergence of new business networks. This material-related process and the ongoing digital transformation of business form an interesting context for an empirical-based analysis of changing interaction and networks. This paper gives the first insights into how digital transformation can benefit the evolution of the network.

Keywords Interaction, Construction industry, Relationships, Digital transformation, Construction 4.0, Cross-laminated timber

Paper type Research paper

1. Introduction

Companies are experiencing continuous demand for renewing their operations and relations with other actors. A fundamental change marking business today is increasing digitalization. Embedded in organizations' structures and activities, information systems (together with novel digital technologies) have enabled organizations to accomplish their daily operations and activities in a more effective manner. The pervasive digital infrastructures and digital innovations benefit not only organizations but also their stakeholders. Pervasive digital infrastructures and rapidly evolving digital technologies have enabled the emergence of new business models, new customer experiences and new value creation possibilities in the entire business network of an organization (Baber *et al.*, 2019; Berman and Marshall, 2014). To explicate the extensive effects of novel digital technologies and innovations, the concept of *digital transformation* has been applied to describe "the changes that the digital technology causes or influences in all aspects of human life" (Stolterman and Fors, 2004, p. 689). Indeed, the novel digital technologies have caused a systemic change for humans, industries and societies, and this has led Berman and Marshall (2014) to call digital transformation a paradigm shift.

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Regardless of the enormous impact and potential that the rapidly evolving digital innovations engender for businesses, the deployment of new digital solutions in an organization is not a trivial task. Going along with digital transformation is a strategic decision, and it requires investments in technologies, skills and capabilities. Therefore, the involvement of the top management is central when adopting and deploying new technologies. In addition, digital transformation goes beyond the organization and concerns its business networks. Actors embedded in the business network are connected by interorganizational relationships, through which the actors interact and build on shared culture, skills and technologies. Because of the connectedness, changes in the technologies, capabilities and skills of any actor influence the entire business network and its actors (Håkansson and Snehota, 1989). Therefore, to understand digital transformation, it is vital to evaluate its influence on organizations, existing networks and industrial sectors.

The construction industry is one of the many branches that are strongly influenced by changes in digitalization and demands for sustainable development. However, it has been criticized for being conservative and reluctant to adopt new innovations (either industry/material-specific innovations or digital innovations) that would foster the construction industry transforming its business for it to be more sustainable. Moreover, fragmented business structures and temporary business contracts with a variable number of sub-constructors have limited the emergence of new innovations within the industry, which has then hindered the renewal of the whole construction industry (Alaloul *et al.*, 2020; García de Soto *et al.*, 2019; Kozlovska *et al.*, 2021; Oesterreich and Teuteberg, 2016). This study investigates changes in the construction industry that are caused by innovative uses of wood as a construction material. Our contribution in this explorative study lies in combining the perspective of business networks (in essence, connectedness) and the all-embracing digital transformation to see how the presumably conservative and fragmented industry has related to the material-related innovation.

The adoption of ecologically friendly innovations and the use of renewable wood materials [such as cross-laminated timber (CLT)] in construction works is on the increase in both private and public construction projects. CLT is a solid wood board (Puuinfo, 2020) that is made of coniferous wood (like spruce and pine) or deciduous wood. This novel wood material (CLT) was originally developed in Central Europe in the search for more ecological alternatives to concrete material. As a result of this intensive research work, CLT material and CLT construction were introduced to the construction industry in the early 1990s (Brandner *et al.*, 2016; Franzini *et al.*, 2018). In CLT manufacturing and construction, information systems like enterprise resource planning (ERP) tools have been applied to enhance the industrial-scale CLT manufacturing and construction. Usage of the industry foundation classes (IFCs) model is emerging and sensor technologies have been experimented with as well.

This study aims at understanding how digital transformation occurs in the business network that has emerged around CLT construction. The analysis covers two intertwined change processes: the emergence of a new technical solution for building (that is, using CLT, which is an environmentally friendly way of constructing) and the adoption of digital Construction 4.0 solutions (which creates efficiency in operations). We use the concept of a business network to describe and analyze the development of CLT construction in Finland. We build on the so-called industrial marketing and purchasing perspective on business markets and its notion that no firm is an island; rather, firms are connected to and influenced by other firms and organizations (Håkansson and Snehota, 1989). The network perspective points to the role of connections through relationships (Möller and Halinen, 2017) and the connected change within a business network (Halinen *et al.*, 1999) as an explanation for innovation adoption (such as CLT adoption). Hence, we direct our focus onto the connected actors within an industry in our investigation of why and how CLT is adopted for construction and how digital transformation can contribute to its use. We will start the analysis by outlining the actors in the business network that is emerging around CLT construction material and the CLT construction method. Then, we discuss their perspectives on and experiences in the digitalization of the construction industry.

Currently, legislation in Finland is forcing the construction industry to consider more sustainable actions, as well as fostering the adoption of new digital technologies and systems within the construction industry. This study is timely, as shown by, for instance, the fact that the Ministry of the Environment in Finland has initiated a process to reform the Land Use and Building Act in Finland (Rautiainen, 2021). This new legislation is targeted to come into effect in 2024 (Ministry of the Environment, 2022). The primary purpose of the reform is to ensure that the carbon neutral goals are met, but additionally, the reform aims at strengthening the quality of construction and digitalization endeavors. To carry out the reform, the Ministry of the Environment is developing a nationwide information system for the built environment (Ministry of the Environment, 2019). Also, the research was carried out at a time when wood construction was gaining particular attention in Finland. As part of national climate strategy, the Finnish Government initiated a Wood Building Program (2016–2022), the goal of which is to double the usage of wood in construction works (Ministry of the Environment, 2020). The increase of using wood in construction is justified by its properties: wood is a renewable and recyclable material, and it also acts as a carbon storage in buildings. The study by Makkonen (2018) indicated that many actors of the Finnish wood products industry have not yet internalized what digitalization actually means. This leaves space for recognizing untapped business potential and enhancing customer value and profitability (Makkonen, 2018).

This study, thus, fills the empirical gap relating to the studies in Finland about digitalization and the emergence of large-scale wood projects (CLT projects) in the construction industry. This study has, moreover, societal relevance and significance for the construction industry, as it addresses the globally relevant change processes concerning digitalization and sustainability in the construction industry. We seek to identify actors in the (emerging) business network of CLT manufacturers and their perceptions of relevant interaction relationships for CLT business; we also aim to explore the current state and deployment of Construction 4.0 solutions in this CLT network.

This paper is organized as follows. Section 2 provides the general theoretical base for the study by presenting an overview of the related literature on business networks and the digital transformation of organizations. Section 3 discusses the industrial background, that is, Construction 4.0 solutions and CLT material. Section 4 describes the methodology used in this study (qualitative interviews). Section 5 introduces the results of the empirical context: actors in the Finnish CLT construction network and the adoption of Construction 4.0 solutions (and, thus, digital transformation) in the CLT network. Section 6 discusses the implications of these results, and Section 7 provides conclusions and study limitations.

2. Theoretical background

2.1 The context of a company: the business network

Our understanding of networks builds on the notion of interorganizational relationships that extend beyond the individual (construction) project. This industrial network approach (often referred to as *the industrial marketing and purchasing approach*) (Håkansson and Snehota, 1995), which emphasizes embeddedness and networks involving actors from different sectors, has increasingly been used to analyze the construction industry (Bygballe *et al.*, 2010; Dubois and Gadde, 2002). This empirically based model of construction (Bygballe *et al.*, 2013) is well suited to our approach to the current developments in the area of construction transformation.

We follow the view of Håkansson and Ford (2002) that a *network* is a structure of opportunities and constraints for strategic action. Therefore, the change toward using more wood, in particular CLT, in construction can only take place if several interconnected actors go along with the change. Thus, to be effective, a change initiated by any actor needs to influence and be adopted by other actors, as well as create network-level change (Halinen *et al.*, 1999). Moreover, as shown by Möller and Halinen (2017), the network-level features (for instance, high goal complexity and value-system innovativeness) influence managerial activities: in our case, for an innovation, such as CLT construction, to be more widely adopted, the need for managerial visioning and influencing is apparent.

Construction projects are complex (Dubois and Gadde, 2002), and they bring together a diverse range of professional experts who design, build and manage the projects. Chan (2016) proposed that expertise in construction is tacit, as well as interactional, intuitive and incidental. The idea of the interactional development of expertise resonates well with our view of construction being built in interaction in networks. By bringing in the factor of digitalization, we ponder on the point of making interaction more explicit and transferable. On the other hand, a study among Finnish sawmills showed that firms in the industry engage in little strategic cooperation (Toppinen *et al.*, 2011), which raises the question of if other forms of interaction take place between the actors in the CLT business networks. Expertise on sustainable construction is also very much in the making, as it is a relatively new area in which different actors (e.g. regulators and companies) are facing new information and demands (Salmi *et al.*, 2022). Indeed, given that the construction sector is characterized by strong path dependencies and lock-in (Hurmekoski *et al.*, 2015), the systemic change toward sustainable construction is not without problems.

Network scholars emphasize cross-sectoral collaboration and the relevance of different kinds of actors (Håkansson and Snehota, 1995). The ongoing change processes in construction call for innovations and new behaviors from actors on a broad front. Construction studies often depict networks showing how the different actors (e.g. architects, structural designers, constructors and owners) become involved and are active at different stages of the construction process (Slaughter, 2000; Hurmekoski *et al.*, 2015). Our understanding of networks builds on the notion of interorganizational relationships that extend beyond the individual (construction) project. Furthermore, it expresses the importance of both direct and indirect relationships in the broader network of relationships. For this conceptualization, see also the work of Bygballe *et al.* (2013) and Dubois and Gadde (2002).

Scholars analyzing business networks and business relationships have directed attention to information technology issues as well. Pagani and Pardo (2017) address digital transformation in a business-to-business context and use the business network model (Håkansson and Snehota, 1995) as a basis for their theoretical framing. Accordingly, they posit that digitalization may modify interaction between business actors in different ways and distinguish between activity-links-centered digitalization, resource-ties-centered digitalization and actor-bonds-centered digitalization. Recently, Ekman *et al.* (2020) analyzed IT portfolio development and the interaction capabilities of business firms and showed the importance of adopting an interorganizational perspective (a dyadic or network perspective) rather than a solely organizational perspective. They noted the important role of interactions in business relationships at both the organizational and individual levels. Furthermore, they show how part of the interaction is of a technical nature, closely associated with digitalization, which they refer to as *high tech* interaction. The other area of interaction is described as *high touch* interaction, which is manifested in interpersonal interactions and emphasizes social and institutional norms. Their study shows how important it is for a company to have interaction capabilities in both of these areas (high-tech and high-touch areas). Similarly, Turk and Klinc (2020), who analyzed the role of IT in construction design, raised the importance of considering social networks in construction in addition to the prevailing view of focusing on product and process. Their framework of construction builds on social interaction and integration. In addition, they stressed the tight linkages between academia (research and education) and industry (practices).

According to the network perspective, an individual actor cannot bring about change on its own. Halinen *et al.* (1999) conceptualized the process of change in business networks, identifying dyadic changes (taking place within a relationship between two parties) and network changes (when the change becomes adopted by several network actors), as well as two types of change: radical and incremental change. The adoption of new technologies may be incremental, but it is central that changes become “network changes”; otherwise, single entities (companies or partnerships) may go along with the change, but it is not accepted by others and the benefits of the innovation are not reaped. This view on network change will direct our analysis of the transformation of the network created around CLT manufacturers.

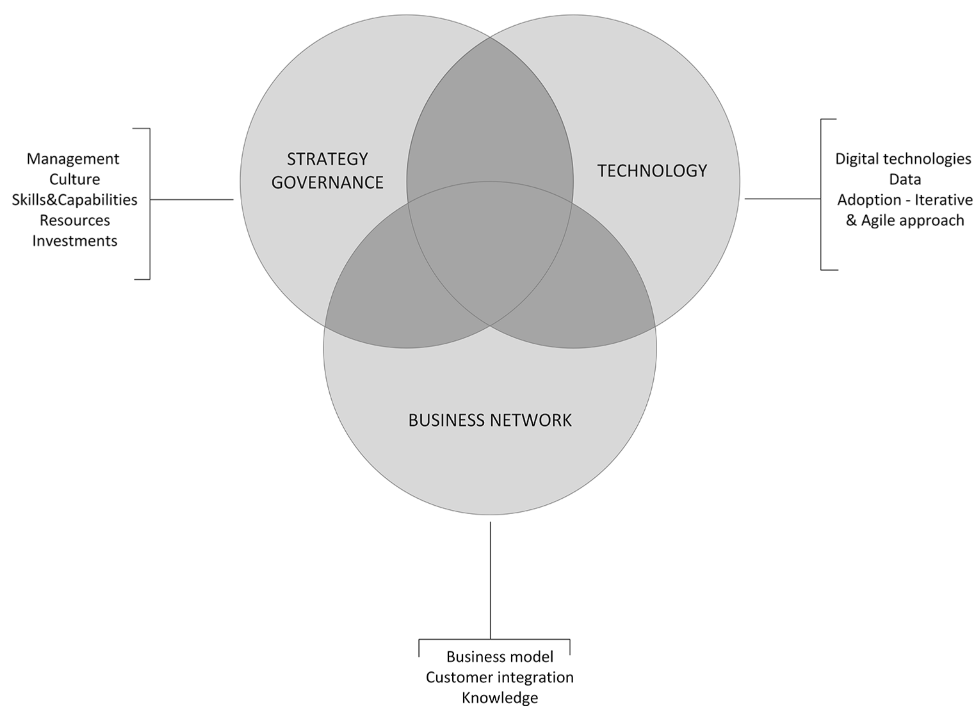
2.2 The digital transformation of an organization

Information systems are an integral part of modern organizations. Diverse digital solutions are embedded in the organizational structures and processes to assist the organization to fulfill its activities and improve its overall performance. However, applying novel digital technologies and solutions to the existing structures and processes is not a trivial task. The process of digitally transforming an organization is multifaceted, and the implementation of digital technologies contains many uncertainties and complexities (Hess *et al.*, 2016; Sahu *et al.*, 2018; Tabrizi *et al.*, 2019). Therefore, an organization needs knowledge and skills in how to execute digital transformation, because digital transformation has broad impacts on both *organizational dimensions* and *business dimensions* (Hämäläinen, 2019). This concerns the focal company as well as other actors in the business network. It is emphasized that organizations should have a *strategic focus* on the long-term digital transformation (Chanias and Hess, 2016a; Tabrizi *et al.*, 2019). This is justified by the observation that digital transformation requires significant changes in, for example, an organization's culture, behavior and mindset; hence, transformation influences individuals and organizations and alters the way in which they perceive themselves and other actors in, for example, business networks in the present and in the future (Figure 1).

A digital transformation strategy requires a holistic view and manifestation from the top management to carry out and invest sufficient resources (both financial and non-financial resources) in digital transformation implementation. A strategic-level focus on digital transformation assists an organization to evaluate, manage and govern the organization's digital transformation journey (Chanias and Hess, 2016a, 2016b) and to consider digital transformation's influences on the organization's structures, processes, stakeholders and business models (Hess *et al.*, 2016; Morakanyane *et al.*, 2017). A digital transformation strategy also assists management to systematically review risks and set indicators to measure the performance and outcome of the digital transformation (Hämäläinen, 2019). Furthermore, developing a specific culture for digital transformation supports establishing a "digital mindset," which has been proven to reduce internal resistance and remove barriers when an organization is carrying out its digitalization efforts (Anderson and Anderson, 2001; Gimpel *et al.*, 2018; Manzoni *et al.*, 2017; Tabrizi *et al.*, 2019).

Following the work of Fitzgerald *et al.* (2014), an organization's main motivation for deploying digital technologies is to improve businesses and evaluate how digital technologies add value for the organization and its stakeholders in the network. The changes in customer needs and behavior have been the trigger points that have catalyzed organization to commence their digital transformation journey. As businesses have shifted from being brick-and-mortar businesses to operating in the digital business environment, the organizations have needed to re-evaluate their business models. Companies have been forced to digitalize their business processes, including customer and user processes, to fulfill the demands of their customers. Furthermore, competitors' digital actions and new entrants from other industries have expedited the digital transformation efforts and fostered the organizations re-evaluating their business models and value creation in business networks (Chanias, 2017; Chanias and Hess, 2016a, 2016b; Fitzgerald *et al.*, 2014; Sahu *et al.*, 2018). It is noted that the

Figure 1 Dimensions influencing an organization's digital transformation



competitors who have adopted modern digital technologies early on and digitalized their services and processes have gained competitive advantages concerning, for example, growth in revenue and profit margins (Chanias, 2017; Chanias and Hess, 2016b; Fitzgerald *et al.*, 2014).

The shift from the traditional business environment to digital business platforms has also influenced and altered the business models of actors in supply chains and business networks. It is noted that the digitalized business environment makes business networks more transparent but may simultaneously fragment or even disrupt the businesses of existing business networks (Berman and Marshall, 2014; Pagani, 2013). Obviously, digitalized business operations represent a new form of market structure and digital platforms open up the horizon, offering products and services globally for existing and new customers (Gimpel *et al.*, 2018; Pagani, 2013; Sebastian *et al.*, 2017). Data engendered in digitalized business operations also extend possibilities to consider more sustainable business solution. Therefore, it is vital for management to consider how digital transformation influences existing businesses, business models and business networks and to evaluate if novel digital technologies also enable the emergence of new business networks and potentially value creation and capture points in cross-boundary networks (Berman and Marshall, 2014; Pagani, 2013; Pagani and Pardo, 2017).

3. The industrial background

3.1 Digital technologies in the construction industry: Construction 4.0 solutions

The manufacturing industry, in particular, has been the pioneer industry when it comes to adopting Industry 4.0 technologies to enhance the efficiency and productivity of the industry (Alaloul *et al.*, 2020; Oesterreich and Teuteberg, 2016). Industry 4.0, which often is labelled as "the Forth Industrial Revolution" (Oesterreich and Teuteberg, 2016), implies the integration of cyber-physical systems within the company and also within organizations operating in the company's business network. *Industry 4.0* covers, inter alia, connected IT systems and a variety of emerging digital technologies, like the Internet of Things (IoT), artificial intelligence, augmented reality and virtual reality. Industry 4.0 technologies allow organizations to build connectivity between physical and virtual objects. The benefit of the connectivity is that it enables increased interaction with physical and virtual entities, which, in turn, magnify the quantity of data. The increased amount of data fosters learning and the development of new innovations and services within the organization (Alaloul *et al.*, 2020; Kozlovska *et al.*, 2021). Therefore, identifying and describing data flows, processes and analyses are integral parts of Industry 4.0's implementation (Kozlovska *et al.*, 2021; Oesterreich and Teuteberg, 2016).

The construction industry has slowly followed in the steps of the manufacturing industry and adopted the same digital solutions and processes that are involved in Industry 4.0. The concept of *Construction 4.0* is proposed to describe the digital transformation of the construction industry. In academia, the Construction 4.0 concept has been an attractive research field for investigating the digitalization of the construction industry and how, by means of Construction 4.0 technologies, the industry may amplify sustainability within the industry (Oesterreich and Teuteberg, 2016). As the concept of Construction 4.0 originates from the concept of Industry 4.0, it has similarities as regards the technologies and concepts involved. However, slight differences exist (Kozlovska *et al.*, 2021; Oesterreich and Teuteberg, 2016). The digital technologies and solutions that have clearly engendered added value for construction professionals are building information modeling (BIM), IoT and radio frequency identification (RFID) technologies (Boton *et al.*, 2021). The sensor technologies (like IoT and RFID) have been used in construction sites to control and track construction entities like construction materials, machines and workers. The IoT and RFID technologies have assisted in optimizing the placement of machines in construction sites and monitoring the material flows and deliveries in supply chains. As a result, the number of thefts has decreased, which in turn has reduced losses of materials and equipment and the need for an inventory on construction sites. Obviously, sensor technologies also improve waste prevention and reduce unnecessary traffic in construction sites. For workers, the sensor technologies have improved work safety, as the construction operators may monitor the accidental and unauthorized use of equipment on a construction site. Sensor technologies, together with augmented reality and virtual reality technologies, have reduced the risks related to workers' health and safety (Kereri and Adamtey, 2019; Osunsanmi *et al.*, 2020).

Other digital technologies that are recognized to add value for stakeholders in the construction industry are BIM, big data and cloud computing solutions (Boton *et al.*, 2021; Kozlovska *et al.*, 2021). BIM appears to be the most adopted and exploited digital solution in Construction 4.0 (Boton *et al.*, 2021; Kozlovska *et al.*, 2021). BIM technology originates from computer-aided design (CAD) technology, which already emerged in the 1980s to assist industrial designers to create digital three-dimensional (3D) artefacts and objects. In construction projects, the ground for BIM is formed in the design phase, when the design team [architectures, civil and structural engineers, constructors and heating, ventilation and air conditioning (HVAC) and electrical designers] initiates a digital data model of the construction work (Lu and Korman, 2010; Naneva *et al.*, 2020). The created data model consists of a significant amount of visual and non-visual data, which is integrated from different data sources engendered by the actors in the construction design team. A data-enriched data model also provides the foundation for the creation of a dynamic digital twin. Creating a dynamic digital twin means transforming a static CAD data model into a dynamic model by integrating both historic and real-time data both from the object itself and also from other cyber-physical systems. A dynamic digital twin is well-adopted technology in the areas of manufacturing and aerospace; to an increasing extent, digital twin technology is also deployed in built environment planning (Hämäläinen, 2021).

Additional to static and dynamic data models, BIM is also referred to as "a set of interacting policies, processes and technologies" (Succar, 2009). Standardized BIM contains guidelines for the processes and policies that form the basis for transparent collaboration and data sharing during the different stages of a construction initiative (Boton *et al.*, 2021;

Osunsanmi *et al.*, 2020). Applying standardized BIM principles in a construction project will, with no doubt, reduce misunderstandings and uncertainties, as all the actors involved in a construction project use the same processes and versions of the data models throughout the lifecycle of the construction work (from the design phase to the construction and operation phases) (Lu and Korman, 2010; Succar, 2009). Standardized BIM also sets guidelines for legal, responsibility and ownership questions asked during and after the construction project (Volk *et al.*, 2014). Cloud computing and big data solutions have been found to be enablers of data collection and analysis. In the construction industry, data is used to, for example, optimize resources (human and material resources), predict and analyze performances and to improve the overall management of a construction project (Bilal *et al.*, 2016).

3.2 Prefabricated cross-laminated timber in construction works

Global pressure for less carbon- and energy-intensive construction has created interest in using wood material in large-scale construction projects. The strategic aims of the forest and construction sectors in Europe are to reduce the environmental impact of construction by 30% and to simultaneously triple the amount of green building by 2030 (Hurmekoski *et al.*, 2018b). The development of CLT material aims to respond to this call and provide more ecological and environmentally friendly construction. After intensive research and development work, CLT was introduced to the construction industry in the early 1990s (Franzini *et al.*, 2018). CLT is a flexible and light building material that complies with the needs of small- and large-scale construction works, like detached housing, wooden multistory projects and public construction projects. CLT material is composed of uneven layers of crosswise glued boards that are made of coniferous wood (like spruce and pine) or deciduous wood. The crosswise layering technique enables the elimination of shrinkage and swelling of the CLT (caused by humidity), making CLT a stable material in diverse construction works. Further, CLT's physical and technical properties – like its lightness, strength and load-bearing capacities – allow the hybrid usage of CLT with materials like concrete and steel in high building construction projects (Brandner *et al.*, 2016; Van De Kuilen *et al.*, 2011).

The innovative CLT material opens up new dimensions for the traditional construction industry. First, CLT influences construction procedures and leads to a more innovative and ecological construction culture. CLT enables the transformation of site-bound construction work into prefabricated housing production. This means that a construction project can exploit the benefits of industrial manufacturing, as prefabricated CLT panels are produced indoors in factory facilities and, thereafter, the further processed CLT walls and floors are transported directly from the factory to the building sites for erection. The prefabricated CLT material, thus, shortens the overall construction time (from design to the supply) of the building, making CLT construction work less damaging to the environment and the surrounding inhabitants. The shortened lead time of a building project reduces the overall traffic involved in construction work and reduces noise pollution as prefabricated and lightweight CLT panels are easy to fasten and installation occurs rapidly on-site (FB Innovations, 2019; Van De Kuilen *et al.*, 2011).

Despite the numerous beneficial properties of CLT, certain factors hinder its adoption in the construction industry. The barriers identified as impeding the adoption of CLT materials in construction projects relate to buildings' physical and technical properties, like a building's structures, fire safety requirements, acoustics and humidity issues. However, the dominant position of concrete and steel materials in the construction industry seem to be the major obstacle. Over the years, the organizations in the construction industry have developed production systems and processes, standards, infrastructures, skills and knowledge to support the usage of concrete and steel materials. Well-established construction practices have caused structural inertia and led to "business as usual" thinking in the construction industry. Indeed, the strong path-dependent culture and active lobbying of the concrete industry have been the major reasons preventing the adoption of more sustainable materials (like timber) in construction projects (Franzini, Toivonen, and Toppinen, 2018; Hurmekoski *et al.*, 2018b, 2018a). Simultaneously, societal demands for more sustainable construction are becoming stronger, as indicated by, for instance, the reform launched by the Ministry of the Environment (2019). Accordingly, it is proposed that presenting a building's carbon footprint assessment is mandatory to receive a building permit for new construction works. This exemplifies the urgent need for developing both new sustainable construction methods and digital tools to evaluate and indicate their features.

4. Methodology

CLT, a wood-based material, is a relatively new, but developing, construction method in Finland. To understand this field, it is vital to identify the actors in industrial CLT construction and also to increase our understanding of how CLT construction may alter the dynamics in traditional (concrete) construction. With respect to digital transformation in a CLT business network, Makkonen (2018) found that many actors in the supply chain of the Finnish wood products industry have little knowledge about digitalization. Explicit knowledge about and insights into how digital transformation (the deployment and adoption of Construction 4.0 solutions) occurs in the CLT business network is needed to improve the understanding of the interdependency of digital transformation and the adoption of sustainable wood-based CLT construction.

To extend the understanding of this novel study phenomenon, we applied a qualitative research method with an exploratory approach. For our data, we rely on 14 interviews with 13 company representatives of CLT construction. CLT manufacturers form a focal point for our analysis of the business network that has emerged in Finnish CLT construction. Table 1 shows the details of the interview data sources. In addition, we resort to secondary data provided by (online) industry workshops focusing on wood construction and/or digitalization in construction.

We conducted semi-structured interviews from May 2020 to March 2021. The interviews were personal one-to-one meetings organized online (because of COVID-19). The interview

Table 1 Research data – interviews and secondary data

#	Company's role in business network	Role of the respondent	Interview method	Length (mins)	Date
1	CLT Manufacturer	R&D, Sales	Telephone	50	29-09-2020
2	CLT Manufacturer	CEO	Face-to-Face	48	26-03-2021
3	CLT Manufacturer	Sales Director	Teams	53	04-03-2021
4	CLT Manufacturer	Digital Product Manager	Teams	45	15-05-2020
5	Element producer	CEO	Zoom/Teams	60 and 30	14-5-2020 and 8-6-2020
6	Construction company	CEO	Face-to-Face	55	14-08-2020
7	House manufacturer	CEO	Teams	60	19-05-2020
8	Structural engineer	Director	Teams	52	27-05-2020
9	Architect	Architect	Teams	55	15-06-2020
10	Architect	Architect	Teams	30	18-11-2020
11	Municipality	City architect	Teams	51	26-05-2020
12	Customer, B2B	CEO	Teams	30	09-06-2020
13	Adhesive producer	Global Market Strategy	Teams	27	26-03-2021
Secondary data	Topic	Organization/Speaker	Media		Date
1	National goals for Timber construction	Ministry of Environment, Finland	available at: www.youtube.com/watch?v=_bL3X7xm9dE		08-09-2020
2	Actual Research Activities, Applications and Future Prospects for CLT	Svenskt Trä/Prof. Schickhofer, Gerhard	available at: www.youtube.com/watch?v=eLAyOb2vow0		ref. September/2020
3	Buildings¨ lifecycle management with BIM	Polytechnic of Karelia/Multiple speakers	Link available upon request		19-05-2020
4	From timber or timber, or something else?	A-Insinöörit/Henri Salonen	Go-to-webinar. Link available upon request		10-06-2021

protocol was formed around three thematic areas: the key actors in CLT construction; views on the interviewee's organization's relationships with other actors in the CLT network; and the digitalization, deployment and adoption of Construction 4.0 solutions within the organization and in the CLT business network. Interview data is based on the perceptions and experiences of the interviewees in reference to the actors in the CLT business network and the relationships between them. The respondents were also asked to present their insights into the current digital tools and solutions applied within their organization and asked to identify the most important digital solutions relevant to their organization and/or to the actors in CLT construction. The respondents were also asked to identify elements that either hinder or accelerate digital transformation in their organization.

The case material was analyzed using an inductive strategy as we were interested in the themes emerging from our rich data (Eriksson and Kovalainen, 2008, p. 129). We used inductive content analysis to decode and sort the content of the data into meaningful categories and abstractions. Content analysis is seen as a valid method for analyzing explorative research, especially in cases where the study phenomenon is unfamiliar and previous research is scarce (Hsieh and Shannon, 2005; Elo and Kyngäs, 2008). Before commencing data analysis, the transcribed interviews were read through several times. Thereafter open codes (like distinguishing significant actors, recognizing digital solutions and adoption of Construction 4.0 solutions) were identified to find similarities and differences between the responses. Open codes assisted to abstract the data and form meaningful categories related to the thematic areas of the study (e.g. relevant actors and their relationships and adoption of Construction 4.0 solutions).

When illustrating the respondents' views in our study through quotes, we detail the background of the respondent (the type of firm they work for) to contextualize their comments. Otherwise, the respondents are kept anonymous. The study is explorative and descriptive by nature. When discussing the results, we explicate the noted interaction and relationships between the actors because these are the potential venue and outcome of digital transformation. To illustrate the current digital transformation prevailing in CLT construction, we report the views of the different respondents in detail; this explicates the different actor perceptions as well as the current concrete tools and solutions for digitalization.

There are four key CLT manufacturers in Finland: one large multinational company and three smaller companies. All of them (represented by Interviewees 1, 2, 3 and 4) were reached for the study. We extended the interviews from the manufacturers to other related actors to form an understanding of the CLT business network. Interviewee 5 represents a CLT element producer. Two interviewees offered the perspectives of construction companies: One construction company (represented by Interviewee 6) has been a pioneer in developing building practices for CLT multistory houses in Finland; the other company (represented by Interviewee 7) has already operated for 40 years in timber construction markets. To investigate the role of design teams in CLT construction projects, we interviewed a structural engineer (Interviewee 8) and two architects (Interviewees 9 and 10). A city architect (Interviewee 11) represents the public sector (municipalities) in our study. This respondent was involved with the first eight-story residential CLT building project in Finland. Finally, we conducted an interview with one customer (Interviewee 12) and one supplier (an adhesive producer) (represented by Interviewee 13).

5. Results

5.1 Interacting actors in the cross-laminated timber business network

All the interviews started by uncovering the CLT manufacturers' primary business partners and perceptions of the connections in the network. As far as the most important business partners are concerned, all the CLT manufacturers noted they included construction companies and material suppliers (mainly sawn timber and adhesive). A close collaborative relationship between the CLT element producer (represented by Interviewee 5) and the CLT manufacturing company (represented by Interviewee 2) was noted as well. The role of designers and/or a design team (including industrial engineers and architects) was emphasized. Interviewees 1 and 5 noted that major errors and cost differences occur in design phase. Designers' poor design and communication with CLT manufacturers and construction companies have resulted in failures (e.g. in CLT board manufacturing, jointing and assembly) in CLT construction projects, which in turn have negatively affected reputation and acceptance of CLT in construction works. In addition, several interviewees noted the role of logistics or assembly companies. Cooperation with universities, researchers and start-ups came up in some replies. Some respondents mentioned property developers, as well as actors from the public sector (municipalities) and financial sector. Table 2 illustrates the perceptions of the respondents as far as their relationships with other actors in the CLT construction network are concerned.

As emphasized by a CLT manufacturer (represented by Interviewee 3), CLT manufacturing is a material-dependent business. Therefore, the suppliers of raw materials (like sawn timber and adhesive) are central in the CLT manufacturing

Table 2 The relationships in cross-laminated timber construction that were recognized by the respondents

#	Respondent	Relationship with design team	Relationship with material suppliers	Relationship with others
1	CLT Manufacturer	x	x	Shareholders, investors, construction companies, logistics, institutions
2	CLT Manufacturer	x	x	Shareholders, assembly, institutions
3	CLT Manufacturer	x	x	Logistics, institutions
4	CLT Manufacturer	x	x	Property developers, institutions, assembly, start-ups
5	Element producer	x	x	CLT manufacturers, construction companies, logistics, institutions
6	Construction company	x		CLT manufacturers, logistics, assembly, institutions
7	House manufacturer	x	x	CLT manufacturers, local construction companies, logistics, assembly, institutions
8	Structural engineer	x		Construction companies, institutions
9	Architect	x		CLT manufacturers, construction companies, institutions
10	Architect	x		CLT manufacturers, construction companies, institutions
11	Municipality	x		Institutions
12	Customer, B2B	x		CLT manufacturer, users, institutions
13	Adhesive producer		x	CLT manufacturers

business network. It is advantageous to have the manufacturing facilities close to those of sawmill facilities. The vicinity of the suppliers of sawn timber ensures the quality and availability of timber materials for the CLT manufacturing. Another CLT manufacturer (represented by Interviewee 1) noted that since the company's initiation, its target has been to systematically develop the entire supply chain, because a CLT construction project differs from both traditional construction projects and other timber construction projects. Similarly, the construction company (represented by Interviewee 7), which has long experience in timber construction markets, highlighted its well-established business relationships with the actors both downstream and upstream in the supply chain, including customers, owners, investors, architects and material suppliers (e.g. the suppliers of wood elements, doors and windows and insulation). Furthermore, the company has created its own design, production and assembly teams to guarantee the quality of its building projects and ensure high customer satisfaction. The company also collaborates closely with the other regional timber construction companies, municipal authorities and business associations.

Nearly all the interviewees (Interviewees 1–12) emphasized that the design phase and design teams play a critical role. The design team in CLT construction covers actors like architects, structural engineers, HVAC and electricity designers and customers (or the representatives of customers, like constructors or building project owners). In this paper, we will apply the term *design team* when referring to the above-mentioned actors.

The CLT element producer (represented by Interviewee 5) noted that the design team is the primary actor group and an initiator of a new CLT building project. The CLT manufacturer (represented by Interviewee 4) supported this view and emphasized that the design phase and the design team(s) are at the core of a CLT building project, and for this reason, the company will strengthen its collaboration with external CLT design teams. The construction company (represented by Interviewee 6) addressed the issue that, because CLT construction differs from traditional building practices, the design phase and close collaboration with the design team (including CLT production) are vital before commencing CLT building projects. This interviewee stressed that his company has built solid and reliable cooperation with designated design and CLT production planning teams to fulfil the requirements of the customers and to deliver CLT building projects in a timely manner. The following quote from the respondent nicely expresses the difference between CLT building projects and traditional building projects:

> The logic of CLT construction commences from the idea that the whole CLT building project must be fragmented and divided into small enough pieces and that the design of the prefabricated module must be rigorously inspected prior to excavating and earthmoving work being launched on the site. This is the main difference between conventional concrete construction projects and CLT construction projects. (a representative of a CLT construction company).

The reasons for the emphasis on the design and initial phase of CLT construction also become evident in our interviews with the structural engineer (Interviewee 8) and architects (Interviewees 9 and 10). The structural engineer noted that structural design is an essential part of a building project because the building frame cost represents 10–30% of the whole building project costs. The role of a structural engineer is to evaluate the technical conditions and to provide alternative structural solutions for the building. Structural engineers collaborate closely with the other actors in the design team. In turn, the architects expressed that they work closely with different stakeholders in a CLT business network, such as with the design team, CLT manufacturers, municipality officials and authorities (like communal building committees and civil engineers). Indeed, cities (and communes) have the power to influence the material choices (especially in public construction) through land-use planning and construction licensing (Salmi *et al.*, 2022). In our study, the city architect (Interviewee 11) notes the positive attitude of the city toward timber material and its interest in the novel innovation (CLT construction). This also led to the decision to provide a lot for one of the first multistory CLT buildings in Finland.

Finally, the interviewed (private company) customer (Interviewee 12) indicated that environmental and ecological factors were the main reasons for selecting CLT material for a new building project. During the construction project, the customer collaborated closely with the internal actors (e.g. the users of the premises) and external actors (the design team, the CLT manufacturer, constructors and the building inspector). Because of the novelty of CLT material, the customer also collaborated with a professor from a civil engineering research unit to ensure that the construction requirements were met with the new CLT building.

All our respondents stressed interaction and exemplified the wide network of collaborative relationships related to CLT construction. This is an interesting emphasis given that the actors operate in a project-based business that has typically been characterized as loosely coupled (Dubois and Gadde, 2002). As our key purpose was to depict the key actors in the CLT business network (determined by asking questions such as "Who are you dealing/cooperating with?" or "Who are your key partners?"), the discussions may lean on connections and collaboration. Because we did not go further in investigating such collaborations (or in analyzing the activity links or resource ties between the actors, which were the focus of the study by Pagani and Pardo, 2017), we do not know how deep or long term the relationships actually were. However, the unanimous stress on collaboration and connections to different parties in construction leads to the question "To what extent are digital tools relied on in these collaborative relationships?"

5.2 Adoption of the digital solutions: Digital transformation in a cross-laminated timber business network

> Energy is used to fill up Excel sheets and so on. Reporting, follow-up, and ex-post evaluation entail additional work and effort due to insufficient information systems. In order to avoid repeating the same tasks and things, it would be important to have one system in which information circulates. (a representative of a CLT manufacturer)

There appears to be plenty of variation in the adoption of digital tools by the actors in the CLT business network. In the first case, where a CLT manufacturer was represented by Interviewee 1, the interviewee emphasized that current information systems are incompatible and information resides in silos. The company has tried to find a suitable solution from commercial ERP systems, but because of a risk of a "vendor lock-in" situation with ERP providers, the company has not committed to any commercial ERP solutions. However, the respondent underlined the importance of evolving current information systems to avoid unnecessary work. As an example, working time is used to fill out and enter (the same) data into different information systems, which takes extra time and effort. Incompatible information systems have also been shown to prevent efficient data exchange, which makes reporting and follow-up slow and laborious.

Considering the information flow with a CLT design team, the practices for submitting the construction drafting differ. Some designers prefer to submit construction drafting in pdf files, while others use IFC formats. Converting an IFC file into a 3D model is laborious but assists later work on adding, for instance, HVAC information to drafts. So far, the BIM standard is not used in the CLT supply chain, both upstream and downstream, of the company represented by Interviewee 1. The reasons for this are that customers and purchase orders range from single households to multistory buildings, and the knowledge and skills required to use BIM vary significantly among the customers. According to Interviewee 1, BIM might work in larger construction works, but so far, using the BIM standard is considered too big an issue in the CLT business network. Another issue hindering the use of BIM is that CLT is not similarly standardized in Europe. All attempts to harmonize CLT standardization in Europe are currently on hold, which influences BIM's evolvement and usage in the construction industry.

The other CLT manufacturers (represented by Interviewees 2, 3 and 4) supported Interviewee 1 and expressed that the CLT element and construction drawings are either submitted as a pdf file or in IFC format. An IFC file is commonly used in the CLT supply chain, as the IFC format is simple to transform into the DWG (AutoCAD drawing database) format. The DWG format is useful, as it enables the integration and addition of HVAC and electricity drawings into the data model as stated by Interviewee 1. The structural engineer (Interviewee 8) underlined the usage of the IFC format in building design and planning. A common practice is to combine the contents from different actors in building the design team. The native file formats are converted to IFC formats, and later on, detailed data models are combined and unified into one digital model as stated by Interviewee 8.

However, Interviewees 1, 2, 4, 5 and 6 mentioned that transforming IFC and DWG files is not straightforward as the IFC format is not compatible with the other software and information systems used in CLT production. Transforming IFC and DWG files from and to other formats requires lots of manual work (it requires extra time and work from the actors operating in manufacturing and construction activities). This was expressed by Interviewee 5:

> Our production needs data models in 3D that show the places of pipelines, seal wires, and so on. The challenge is if an architect does not draw (design) in a similar way [...] and then we need to make HVAC design and calculation, it is not enough [...] Design software are different, and they do not necessarily communicate with each other. This is the challenge in this type of construction work. (a representative of a CLT element producer)

Interviewee 4 mentioned that incompatible data file formats is an issue, especially with new customers and design teams. To tackle the problem, Interviewee 4's company had even established a specific technical team whose task is to convert building designers' data files to the file formats that are compatible and used in production. Interviewee 8, in turn, mentioned that combining different native file formats and digital interfaces requires some additional work but is not an issue in the current digital building design process. It is, however, notable that incompatible and inaccurate file formats shared between designers and CLT element production impede the process of a CLT construction project (according to Interviewees 4, 5 and 6). Dimensional accuracy is crucial in prefabricated CLT elements, and no design errors can occur between design and production. The actual CLT element must, thus, be exactly as it is in design data files and the frame must be assembled in the correct manner and with the correct tolerance. Otherwise, the whole construction faces delays and financial losses (according to Interviewees 5 and 6). Another informant, Interviewee 9, supported this view and emphasized that designers need to know the correct dimensions and how the joints of the timber elements or box units are made.

One company (represented by Interviewee 4) aims to enhance knowledge of timber construction and is currently developing practical digital tools for CLT building designers. The company has, for example, created BIM files from its CLT elements and developed a specific software that assists designers in simulating CLT elements (roofs and walls) and calculating the technical properties of CLT (such as strength) in different building projects. This free-of-charge software has been well accepted and used, especially in educational institutions like universities. The company has also invested in developing and piloting sensor technologies and other digital technologies (probes, RFID tags, mobile apps and QR codes) that support the use of timber materials in construction works. With the current digital technology pilots, the company aims to enhance the spatiotemporal information of CLT elements and provide information on unexpected incidents, "shocks" (e.g. information on humidity and damage to the consignments). For CLT assembling teams, the company has developed a specific mobile application that assists assembling teams in installing CLT elements in precise places. A mobile application with BIM information simplifies the installation process, making CLT element installation more organized and efficient. One respondent (Interviewee 4) highlighted that novel digital solutions are developed and piloted together with start-ups and customers. Feedback from the customers has encouraged the company represented by Interviewee 4 to develop further novel digital solutions, even though some technical restrictions (e.g. limited sensor battery duration) exist.

Interviewee 5, representing a producer of prefabricated CLT box units, expressed that they are developing the company's information systems to overcome the earlier mentioned data format challenges. The company has applied for external funding to evolve the overall digital capabilities and readiness in the company. The company represented by Interviewee 6 highlighted the need to develop the building design process so that 3D models are created from the very beginning of the design process. However, this development process is still in its infancy. The ultimate goal of the company is that industrial CLT construction design would follow the design principles applied in reference industries, such as mechanical engineering. Each phase of the CLT construction process should be automated and robotized:

> Industrial construction and that type of thinking, that is something that must be developed. Inside the [CLT] factory, it should be the robots who carry out the whole production process. (a representative of a construction company)

In turn, the company represented by Interviewee 7 is investigating possibilities to build from CLT material. The company has well-established relationships with several actors in the building industry. The company has created its own design, production and assembly teams to guarantee the quality of building projects and to ensure high customer satisfaction. The company has invested in and put lots of effort into developing information systems. The company had initially developed information systems in-house, but it has recently acquired software tools and solutions for ERP and building design activities from external vendors. The reason for outsourcing some part of the company's information systems was that the internal ICT developer left the company. Overall, the company has been satisfied with existing digital solutions, and there does not seem to be any acute need to improve or change the current digital systems. Interviewee 7 noted that some older construction workers prefer using traditional building blueprints but found it positive that regional building authorities prefer using digital building blueprints. When asking to recognize future business opportunities in timber construction, Interviewee 7 referred to the regular maintenance activities that wooden buildings require. Integrating digital solutions in a building's life-cycle management, new business activities and models for existing and new actors in the business network of timber construction may arise. The company had experimented with a 3D printing solution to discover technology's applicability in house manufacturing. The results from the experimentation did not encourage the company to continue further as the quality of the 3D printed wood material was not strong enough for wood construction purposes. Material was produced from recycled wood waste.

Interviewees 8, 9, 10 and 11 represent the design phase of the construction work. The structural engineer (Interviewee 8) emphasized that all construction projects are 3D modeled. The design chain, from design to production, must be straightforward, and for this reason, everything must be 3D modeled. Moreover, a 3D model contains all the necessary details, and no "dead lines" exist. This means that the digital version of the building provides such precise information that each actor in the project, from design to production, finds exact and relevant information during the construction project. Compared to the concrete construction industry, Interviewee 8 stressed that the timber construction industry offers, to a limited extent, data models from the timber components, like CLT elements and box units. Reliable data models of the timber components would evidently accelerate designers' work and reduce the risks of design errors. Simultaneously, the availability of the timber component data models in BIM libraries would enhance knowledge and usage of wood in building projects.

The architects (Interviewees 9 and 10) have knowledge about large-scale CLT construction works. Interviewee 9 currently produces two-dimensional construction drafting but is about to upgrade his skills and knowledge level to meet the requirements of 3D modeling. This is because a 3D-modeled building requires less building draft copies and, thus, streamlines the entire building project. Interviewee 10 emphasized that all construction projects, even the small ones, are 3D modeled. Interviewee 10, furthermore, mentioned that the 3D modeling practices in construction design teams are generally well adopted. All stakeholders in the design process have proved that 3D models, together with BIM, are valuable and worth deploying. Data models and BIM assist in sharing skills and knowledge of the CLT material among the parties attending the construction design work. Interviewee 10 emphasized they are able to collect an enormous amount of detailed data for the 3D model; however, not all the information is relevant. Therefore, it is important to determine the level of detail of the collected information to avoid entering unnecessary and invaluable data into the building's data model. Determining the level of detail assists in consideration of the demands and use of the data later in the building's life cycle. Interviewee 10 mentioned that the level of BIM knowledge is relatively weak among the building project owners. The constructors, on the contrary, have noticed that BIM assists them in improving the design of the construction site and the logistics during the construction project. Interviewee 11 did not express any specific viewpoints on whether Construction 4.0 solutions were used during a wooden multistory construction project. However, Interviewee 11 expressed that measurable data regarding the building's carbon footprint and life-cycle costs would be beneficial for land-use planning and decision-making. Interviewees 12 and 13 had little to add about the digital transformation of the CLT business network. Interviewee 12 expressed that he did not use 3D models during construction work. The interviewee for the adhesive supplier reported that a regular ICT system is used within the company.

6. Discussion

CLT construction is a relatively new construction method in Finland, and there are only a few domestic CLT manufacturers. However, sustainability concerns have fostered interest in renewable materials, and CLT is increasingly being adopted in the Finnish construction market. This study set out to explore the emerging business network of CLT construction by depicting the interconnected actors and investigating how digital transformation occurs in this network.

Following the work of Håkansson and Snehota (1989) and Håkansson and Ford (2002), we see that a company is connected to and influenced by other firms and organizations from different sectors. Our study found that the business network of CLT construction consists of industrial CLT manufacturers and their material suppliers, customers (property developers and owners) and external and internal design teams (including architects, structural engineers, construction companies, HVAC and electricity designers and CLT production planning teams), together with logistic and assembly companies. CLT construction is also influenced by investors and municipal officials and authorities (e.g. municipal civil engineers and building committees). The role of other organizations, like universities and business associations, was also highlighted, which illustrates cooperation between managers and researchers (Turk and Klinc, 2020).

When comparing industrial CLT construction with traditional (concrete/steel) construction (where production systems and processes are standardized and matured), we notice that CLT construction is emerging, but the interorganizational relationships in the CLT business network are still fragmented, and cooperation is slowly unfolding (Toppinen *et al.*, 2011; Hurmekoski *et al.*, 2015). While the challenge of the project-based construction industry has traditionally been to develop cooperative interactions (Dubois and Gadde, 2002), our study points to attempts to develop cooperation in CLT construction. Several CLT manufacturers and construction companies have found it advantageous to systematically develop the entire supply chain, both downstream and upstream. However, it is too early to conclude that strong collaborative relationships prevail between the actors in the CLT business network. Rather, further research is needed to analyze the relations in more depth. For stronger relationships to develop, additional knowledge and experience of CLT construction is needed (Chan, 2016). Knowledge of CLT material (its physical and technical properties) and the CLT construction method are especially vital for architects and structural engineers, but construction companies also need to understand how to build with CLT material. Furthermore, the municipal authorities need knowledge about CLT construction, as they have the power (along with architects and structural engineers) to either accept or reject the usage of CLT in new building projects (Franzini *et al.*, 2018; Hurmekoski *et al.*, 2018a; Salmi *et al.*, 2022). The CLT manufacturers also called for better mutual collaboration (with other CLT manufacturers) to promote common interests and the standardization of CLT construction.

In general terms, all the respondents emphasized that interaction, particularly with design teams, and networks of collaborative relationships are needed to increase CLT construction. This emphasis is in line with previous studies on the dynamics of business networks; for a network-level change (like the adoption of radically new ways of constructing) to take place, several actors need to accept and adopt the change (Halinen *et al.*, 1999). Moreover, a network that is characterized by radical changes poses particular managerial challenges and calls for, for instance, visioning and agenda development from managers (Möller and Halinen, 2017). So far, CLT construction has attracted relatively few companies in the Finnish construction industry, and a CLT business network is only emerging. In an attempt to strengthen the existence of the CLT construction, this study suggests that, additionally to the previously mentioned issues (i.e. mutual collaboration, skills and knowledge), the renewal through the adoption of CLT in construction can take place if several interconnected actors go along with the change. CLT construction differs from traditional on-site construction, and collaboration – especially with a design team and CLT production and construction companies – was seen to be essential because errors in the design phase would result in failures in CLT production and would simultaneously delay and jeopardize the whole CLT construction project.

The study of digitalization in the wood products industry conducted by Makkonen (2018) showed the association between digitalization and customer value, but simultaneously, the study underlined that the actors in the wood products industry have not fully internalized what digital transformation means. The literature of an organization's digital transformation calls for a strategic approach and discloses that elements like company size, the industry in which the organization operates, ICT skills and capabilities and management's commitment all influence the organization's abilities to systematically perform digital transformation efforts (Chanias and Hess, 2016a, 2016b; Fitzgerald *et al.*, 2014). The present study shows wide variation in the adoption of Construction 4.0 technologies by the actors, and therefore, digital transformation occurs to different degrees across the CLT business network. We found that the majority of the actors in the Finnish CLT business network are small and medium size companies. Following the work of Oesterreich and Teuteberg (2016), small- and medium-sized enterprises' interest in investing in Construction 4.0 remains modest even though the benefits of such solutions are recognized. Our study shows that, for SMEs, the benefits and return on investment of Construction 4.0 were still unclear because CLT construction (e.g. CLT construction's business, processes and networks) is still evolving. While SMEs strive to develop internal information systems and usage of Construction 4.0 technologies, wider application of, for instance, the BIM standard in the entire CLT business network is currently seen too big an issue. The actors in the CLT business network tend to use different design software and file formats (pdf and IFC) and knowledge and skills required to use BIM vary significantly among the CLT actors (e.g. customers and designers). Moreover, the wide customer range (from single households to multistory buildings) does not support the need for using BIM in a systematic manner. However, one SME respondent emphasized that CLT construction should learn from reference industries (like car industry) and develop CLT construction toward an automated and robotized industrial prefabricated construction. This would require the novel Construction 4.0 solutions to be deployed systematically and design and production processes to be harmonized in the entire CLT business network. Presently, the deployment of Construction 4.0 solutions (that is, digital transformation) in CLT SMEs is still fragmented and less matured, although evolving.

In more established organizations, in turn, the organizations have already created a strategy and culture to carry out digital transformation. For them, the deployment of Construction 4.0 is a strategic issue and the organization's culture and management support the usage of Construction 4.0 solutions (Sebastian *et al.*, 2017; Chanias and Hess, 2016a, 2016b). These organizations also invest in technical and human capabilities to find new approaches to integrating and educating actors (in particular, the building designers) regarding the use of CLT. As an example, one CLT manufacturer publishes BIM files from its CLT elements and provides a specific software for designers so that they can simulate and calculate the technical properties of CLT elements in different building projects. Furthermore, this company supports experimenting with new digital innovations and actively investigates possibilities to develop new (digital) services and businesses to extend CLT construction business.

Evidently, the role of planning and information sharing in CLT projects is particularly critical. The ongoing change processes in construction (including CLT material and digitalization) call for a new culture, mindset, skills and behavior from actors on a broad front. Mirroring the findings of Ekman *et al.* (2020) on high-tech versus high-touch interactions, our study, thus, notes the importance of interaction in a CLT business network on several fronts, including both technical and interpersonal aspects. Digital transformation can enhance the use of CLT in construction, but there is a need for interorganizational and cross-sectoral collaboration to promote digital transformation in the CLT business network. As stressed by network scholars (Håkansson and Snehota, 1989; Halinen *et al.*, 1999; Möller and Halinen, 2017; Pagani and Pardo, 2017), an actor working alone can neither enhance the diffusion of a new innovative and sustainable CLT material nor ensure that digital transformation occurs in the CLT business network. Understanding the benefits and value that Construction 4.0 solutions engender is crucial if the CLT industry wishes to foster the wider adoption of CLT in the Finnish construction market.

7. Conclusions

This study contributes to previous studies by investigating digital transformation in the construction sector in general and in CLT construction in particular. Several of our findings indicate that change indeed calls for the involvement of several actors and takes place in networks. Because of limited knowledge of CLT construction, we emphasize adopting an interorganizational perspective from the very beginning of CLT construction work instead of solely adopting a single organizational perspective. Interorganizational collaboration (closer cooperation with design teams, CLT manufacturers and construction companies, as an example) would contribute to improved expertise and the adoption of CLT in construction projects.

Because digital transformation is occurring to different degrees across the CLT business network, we suggest that the adoption of an interorganizational perspective supports the deployment of Construction 4.0 and enhances digital transformation in the CLT business network. This idea is justified by the number of benefits that BIM implementation has engendered in large-scale infrastructure and building projects in the traditional construction industry. The deployment of BIM would especially benefit the design phase of CLT construction as harmonized design practices extend possibilities to simulate the technical and physical elements of the CLT construction and to detect potential design errors before actual CLT element fabrication and project delivery. The interorganizational perspective, together with BIM implementation, would improve interaction and information sharing, which would, in turn, decrease misunderstandings and the asymmetry of CLT knowledge among actors in existing and new CLT business networks. Further, interactive BIM could reduce inertia among actors who consider CLT construction risky and expensive. As an immediate measure, improving the interoperability of the information systems and solving IFC file's incompatibility challenge are recommended. These would result in more consistent information flows and the efficient usage of data inside the organizations and in the CLT business network. Additionally, upgrading digital transformation capabilities in the CLT business network can open paths to investigating new data-based business possibilities and observing how CLT construction, together with novel digital solutions, can enhance industrial prefabricated construction and thereby foster a carbon neutral construction industry.

The interviewed actors are in the initial phase of CLT adoption and CLT business networks in Finland are only gradually emerging. Furthermore, we did not analyze any particular network in detail, and while representing different positions and roles in the CLT business network, our interviewees only reported individual perceptions. This allowed us to raise current concerns and topics related to CLT building and digitalization, and we did not aim to gather generalized knowledge on the issues. Future studies would benefit from:

- longitudinal studies on the evolution of the CLT business networks over time;
- more detailed analysis of the relationships between the actors in the CLT business network, to understand, for instance, how the digital transformation modifies the activity links and resource ties;
- more extensive, potentially survey-based, studies covering a higher number of actors and, thus, allowing for generalizations; and
- comparative studies on investigating CLT construction in Finland versus countries where the field is more advanced.

Overall, we expect that more advanced CLT construction business will be accompanied by the higher usage of novel digital solutions.

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