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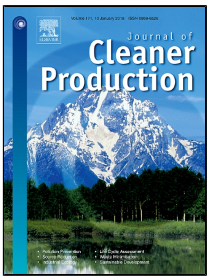

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Highlights

- The Circular Economy requires new types of supply chain collaborations.
- The paper develops a framework for supply chain collaboration in circular buildings.
- Three cases are studied: a new building, a renovation and a demolition project.
- Visions, learning, network dynamics and business model innovation are analyzed.
- A novel collaboration tool for developing circular buildings is developed.

Circular Economy in the building sector: three cases and a collaboration tool

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Abstract

The Circular Economy (CE) gained significant traction in business and academia. While in the building sector issues around energy efficiency are being widely explored, CE is still a relatively new topic. This article reports on three CE pilots in the Dutch building sector and develops a collaboration tool for developing and operating circular buildings and their supply chain collaborations. First, a conceptual framework is developed to study supply chain collaboration in circular buildings, which uses theoretical building blocks for visions, actor learning, network dynamics and business model innovation. Second, a case study is presented where the framework is applied to three cases using semi-structured interviews and document analysis. Third, an empirically-based tool is developed to enhance collaboration for CE in the building sector. The cases include a newly built project, a renovation project and a demolition project. It was found that developing circular buildings requires (i) a new process design where a variety of disciplines in the supply chain is integrated upfront, (ii) the co-creation of an ambitious vision, (iii) extension of responsibilities to actors along the entire building supply chain, and (iv) new business and ownership models.

Keywords: circular economy; industrial ecology; built environment; closed loop supply chain; sustainable innovation; supply chain collaboration.

1. Introduction

The concept of the Circular Economy (CE) is proposed to change current production and consumption patterns that put a significant burden on our planet and its environmental capacity. This requires not only closing loops by reusing 'waste' and resources, but also slowing material loops by developing long lasting reusable products (e.g. Bocken et al., 2016; EMF, 2012; Kok et al., 2013). The concept of a circular economy goes back to Boulding (1966) who wrote about a *"Cyclical ecological system which is capable of continuous reproduction of material form even though it cannot escape having inputs of energy"* (Boulding, 1966, p. 8). Other scholars (Andersen, 2007; Greyson, 2007; Jackson et al., 2014) trace the CE concept back to Pearce and Turner (1989) who worked on a model for a CE. The concept is rooted in Industrial Ecology (IE), which focuses on analyzing and optimizing industrial systems (e.g. Graedel, 1994; Stahel, 1994) and developing a new economic model of production and consumption with closed material loops (Ghisellini et al., 2016; Yuan et al. 2006; Zhu et al., 2011). Cradle to Cradle® (C2C) also links to the CE in its biomimetic approach to the design of products and systems, where biological and technical material cycles are separated (McDonough and Braungart, 2002). Recently, the concept of CE gained ground thanks to the Ellen MacArthur Foundation (EMF) who published a series of reports (EMF, 2012, 2013, 2014) promoting the opportunities of a CE. Several definitions of the CE have been proposed, but in this paper, we build upon the EMF definition (EMF, 2013) that has been widely adopted by industry, government and academia: *"A Circular Economy is an economic and industrial system where material loops are closed and slowed and value creation is aimed for at every chain in the system"*.

Whereas the concept of CE is getting global momentum in politics, business and academia, the knowledge and tools for bringing it into practice still largely need to be developed (Bocken et al., 2017; Lacy and Rutqvist, 2015). This is especially true for the building sector, where innovation diffuses rather slowly (BIS, 2013; Fernie et al., 2006), and where the focus has been on issues like energy use and energy efficiency (Lucon et al., 2014). Indeed, according to the IPCC (Lucon et al., 2014), buildings accounted for 32% of total global final energy use in 2010. Moreover, the building industry consumes 40% of the materials entering the global economy (Khasreen et al., 2009), while only an estimated 20-30% of these materials are recycled or reused at the end of life of a building (EMF, 2014). With an increasing population, there is a dual need for quality retrofitting and sustainable new construction (Lucon et al., 2014). In view of these challenges, many stakeholders regard

the CE concept as an important step to create more financial, social and environmental value by taking a systemic view on the whole life cycle of buildings and by using new technologies and design approaches. This enables to move away from a 'take-make-dispose' paradigm to a circular perspective on material reuse (ARUP and BAM, 2017; Pomponi et al., 2017).

This paper investigates the built environment as a key contributor to problems like resource depletion, climate change and pollution (van Bueren, 2012). Circular principles can reduce the environmental impact of buildings significantly (Circle Economy et al., 2014; Smol et al., 2015). The building and construction sector is one of the five priority sectors in the European CE package (Bourguignon, 2016). Based on the previous discussion, as well as on strategies and principles defined by Lacy and Rutqvist (2015) and Circle Economy et al. (2014) we can define the CE approach for (circular) buildings as *"A lifecycle approach that optimizes the buildings' useful lifetime, integrating the end-of-life phase in the design and uses new ownership models where materials are only temporarily stored in the building that acts as a material bank"*. This definition is more extensive than the one by Pomponi and Moncaster (2017, p. 711) who define a circular building as *"a building that is designed, planned, built, operated, maintained, and deconstructed in a manner consistent with CE principles"*.

This paper emphasizes supply chain collaboration across the entire lifetime of buildings from design to end-of-life. When closing and slowing material loops, it is essential to include the supply chain as a whole, and to involve all parties from design and raw material suppliers to end users, service providers and recyclers, including the associated information flows (Seuring and Müller, 2008). Social relationships and collaboration between supply chain partners are considered key to creating closed loop supply chains (Bocken et al., 2016; Green and Randles, 2006; Lai et al., 2010), and need to be taken into account for a transition towards CE (Genovese et al., 2017; Ghisellini et al., 2016). Based on the concept of sustainable supply chain management and definitions by EMF (EMF, 2013) and Lacy and Rundqvist (2015) we define CE in supply chain collaboration as *"connecting a network of actors in their supply chain by managing data transparency, material flows and exchanges, responsibilities, predictability and sharing benefits"*. This goes beyond the concept of reverse and closed loop supply chains (Genovese et al., 2017; Guide and Van Wassenhove, 2002) by taking a strategic perspective on the new role of organizations to redevelop supply chains through collaboration to close and to slow down resource loops.

This paper uses insights from innovation studies and supply chain management to address the following research question: how can new ways of supply chain collaboration

contribute to the transition towards CE in the Dutch building sector? The focus on circular buildings is particularly relevant for supply chain collaboration because a building is a complex "object" with several layers, such as the facade, the service equipment and the structure (Brand, 1994) each having their own time frame for operation (Pomponi et al., 2017). These different time frames are linked to many parties along a building's supply chain making the closure of material loops along the total lifecycle of a built object highly challenging.

The paper is structured as follows: Section 2 provides a theoretical background through a literature review to analyze CE in building projects, resulting in a conceptual framework. In Section 3 the methodology is described. Section 4 presents three cases. Based on these cases, a collaboration tool for circular buildings is developed in Section 5. Section 6, draws conclusions and includes final reflections on both the conceptual framework and the collaboration tool.

2. Towards a conceptual framework

This section develops a conceptual framework for studying CE in supply chain collaboration in the built environment. It is based on a literature review of several relevant concepts that were identified in the early phase of the study and build on earlier work of the authors (e.g. Kraaijenhagen et al., 2016; Quist, 2007; Quist et al., 2011). The concepts identified include (i) future visions, (ii) actor learning, (iii) network dynamics and (iv) business model innovation, which can all be seen as essential elements for studying CE in supply chain collaboration, cf. Seuring and Müller (2008) and Barratt (2004). Each concept is briefly discussed and described, before combining all concepts into a conceptual framework.

2.1 Visions of the future

Visions of the future are important both in transition studies (e.g. Smith et al., 2005; Quist et al., 2011) and in CE (e.g. Kraaijenhagen et al., 2016; Prendeville et al., 2017), in particular in an early stage when first pilots and demonstration projects are started. Visions do not only provide an image of a possible future, but also provide coordination among heterogeneous actor groups, and guidance and orientation for joint action towards that future (Borup et al., 2006; Quist, 2007;) through collective goals and alternative rule sets (van der Helm, 2009). Future visions can be seen as a key element in the transition to a circular building sector, as well as early demonstrations and pilots.

Analyzing visions and their dynamics can be done in different ways. When looking at CE in supply chain collaboration and circular building pilots, the concepts of future visions as

developed by Quist (2007) and van der Helm (2009) are useful for analyzing visions at an operational level due to their focus on the actual functioning of visions. Van der Helm (2009) provides a framework for analyzing visions consisting of three elements. The first element concerns the transformational elements in a vision, describing the contrast between what is in the present and what could be in the future. Metaphors are often used to describe such transformational elements (van der Helm, 2009). The second element concerns the explicitness of words and images to describe and discuss visions. The third element is about the attractiveness of a vision in the way that it is inspiring, guiding and motivating people (van der Helm 2009). This also relates to leadership for which the term 'vision champion' has been proposed when provided by key persons (Quist, 2007; Quist et al., 2011). Building on the concepts by van der Helm (2009) and Quist (2007), visions are analyzed in this paper as follows:

- Vision image: including (1) potential metaphors used and (2) the explicitness of the vision in words and images (van der Helm, 2009).
- Vision guidance: in (1) clear collective goals, (2) presence of alternative rule sets, (3) leadership (van der Helm, 2009; Quist, 2007).
- Vision orientation: via motivation, inspiration and direction (van der Helm, 2009).

2.2 Actor learning

Learning among different actors involved is another key element in innovation and transition experiments (Brown et al., 2003; Quist and Tukker, 2013) as well as in Strategic Niche Management (Raven, 2005). Although learning starts at the individual level where new information is assimilated and applied in subsequent actions (Hall, 1993), it is used here at the level of actors. Two main types of learning can be distinguished: first order learning and higher order learning (Brown et al., 2003; Raven, 2005). First order learning leads to new insights about options for a particular problem and context, whereas higher order learning can change problem definitions, norms, values, convictions and goals of actors. The latter is needed to implement radical new sustainable solutions and support required change processes (e.g. Quist, 2007). Actor learning is not only an important condition for successful circular building pilots, but also for the transition to circular buildings at large.

Whereas several actor learning concepts can be found in different disciplines (for an overview see Quist, 2007), we employ the frameworks of Brown et al. (2003) and Brown and Vergragt (2008), because of their focus on sustainable innovations in projects with a relatively short time span. Based on the frameworks of Brown et al. (2003) and Brown and

Vergragt (2008), learning in circular building pilots is analyzed by looking whether the following shifts could be identified among actors involved:

- A shift in defining or framing problems (Brown and Vergragt, 2008).
- A shift in problem solving approaches and shifting priorities (Brown et al., 2003).
- A shift in the level of the dominant interpretive and cognitive frames through joint learning and shifting joint opinions among the actors involved (Brown and Vergragt, 2008).

2.3 Network dynamics

Organizations, firms and individual actors in supply chains are linked to each other by different kinds of relationships, which make up a social network (e.g. Boons and Baas, 1997; Gordon and McCann, 2000). Linkages between parties are not only of a technological nature, but also of a social nature (Gimenez and Tachizawa, 2012; Seuring and Müller, 2008). To change linkages in a system, it is important to know how these networks evolve.

Several network theories have been developed in innovation studies and business studies, such as actor network theory (Callon, 1986; Latour, 2005) and industrial network theory (Håkansson, 1987). Supply chains in building projects, as the unit of analysis in this research, can be regarded as a special type of network around material and information flows (Seuring and Müller, 2008). Industrial network theory (Håkansson, 1987) is useful here, because it distinguishes three core elements: (1) actors, (2) resources and (3) activities to combine, exchange or create resources. In doing so, it explicitly deals with exchanges of resources in networks, which is essential in (closed loop) supply chains. Industrial network theory, however, is quite rational in its description of relationships between actors. Hence, for the social dynamics of collaboration, supply chain management is useful. For instance, Barratt (2004) distinguishes: (i) cultural elements, such as trust development (Cheng et al., 2008; Pomponi et al., 2015), (ii) collaboration elements, such as cross-functional activities within or between organizations and (iii) strategic elements, such as organizational support for a pilot project (Barratt, 2004). By combining industrial network theory and elements from (green) supply chain management, we can analyze network dynamics as follows:

- Analysis of actors and their essential activities for the building project (Håkansson, 1987).
- Relationships among actors in terms of (1) the *strategic* element of organizational support, (2) the *collaboration* element of cross-functional activities and (3) the *cultural* element of trust development (Barratt, 2004).

2.4 Business model innovation

For the transition to CE, business model redesign is considered essential in delivering environmental and social value while keeping economic benefits (Bocken et al., 2013; Porter and Kramer, 2011). Business models are a key element in implementing the change to a circular building sector and may include changing ownership of materials and products and servicing these. This requires the creation of value for a network of stakeholders (including Society and Environment), and not only the firm, (Stubbs and Cocklin, 2008; Bocken et al., 2013).

There is a growing body of literature on sustainable and circular business models. For instance, Stubbs and Cocklin (2008) did early work on conceptualizing sustainable business models. Bocken et al. (2014) developed a categorization for archetypes of sustainable business models. Boons et al. (2013) connected sustainable innovations to business models and economic performance, while Boons and Lüdeke-Freund (2013) reported a comprehensive literature review on sustainable innovation and business models and proposed a research agenda. Porter and Kramer (2011) emphasized shared value creation. Most authors distinguish between three elements of a business models: value proposition, value creation and delivery, and value capture (e.g. Bocken et al., 2014; Osterwalder et al., 2005). To identify circularity in business models, both at the level of the case and at the level of individual supply chain partners, we build on the categorization of sustainable business model archetypes proposed by Bocken et al. (2014), and recently updated by Ritala et al. (2018). This categorization includes the following archetypes of business model innovations: (1) Optimize material and energy efficiency; (2) Create value from waste; (3) Substitute with renewables; (4) Deliver functionality; (5) Adopt a stewardship role; (6) Encourage sufficiency; (7) Repurpose for society; (8) Inclusive value creation and (9) Develop scale-up solutions. 'Inclusive value creation' was proposed by Ritala et al. (2018), reflecting the increasing number of peer-to-peer and sharing models.

2.5 Towards a conceptual framework

Based on the literature review and the identified concepts, a conceptual framework has been developed to study supply chain collaboration for CE in the building sector. As shown in Figure 1, it consists of the following building blocks: visions, actor learning, network dynamics and business model innovation. Figure 1 also shows how the building blocks can be used to analyze the cases, for which aspects have been defined. The conceptual building blocks are all related to one another, as discussed below.

Developing and pursuing future *visions* induces *learning* amongst actors, whereas the vision also provides guidance and orientation to the *network* and the actors involved (Quist, 2007; Quist et al., 2011).

When *learning* becomes shared (Brown et al., 2003), this leads to joint understanding and adjustments in the *network*, which may include changes in the cultural, strategic and collaboration elements cf. Barratt (2004).

Industrial network theory (Håkansson, 1987) (*network dynamics*) links to the *business model* that includes organizational aspects in the value delivery part (e.g. Bocken et al., 2013). Barratt (2004) relates strategic elements (of *network dynamics*) to business models that should embed collaboration across the supply chain.

The *business model* and *vision* blocks are linked, as new visions usually require new business models and vice versa (Kraaijenhagen et al., 2016), which is the case for circular buildings. Subsequently, circular business models – e.g. cases where all key materials are leased rather than sold through new types of contracts – require new types of supply chain collaboration (Kraaijenhagen et al., 2016; Bocken et al., 2016). In addition, developing circular business models requires both higher order *learning* and new collaborations influencing the *network*.

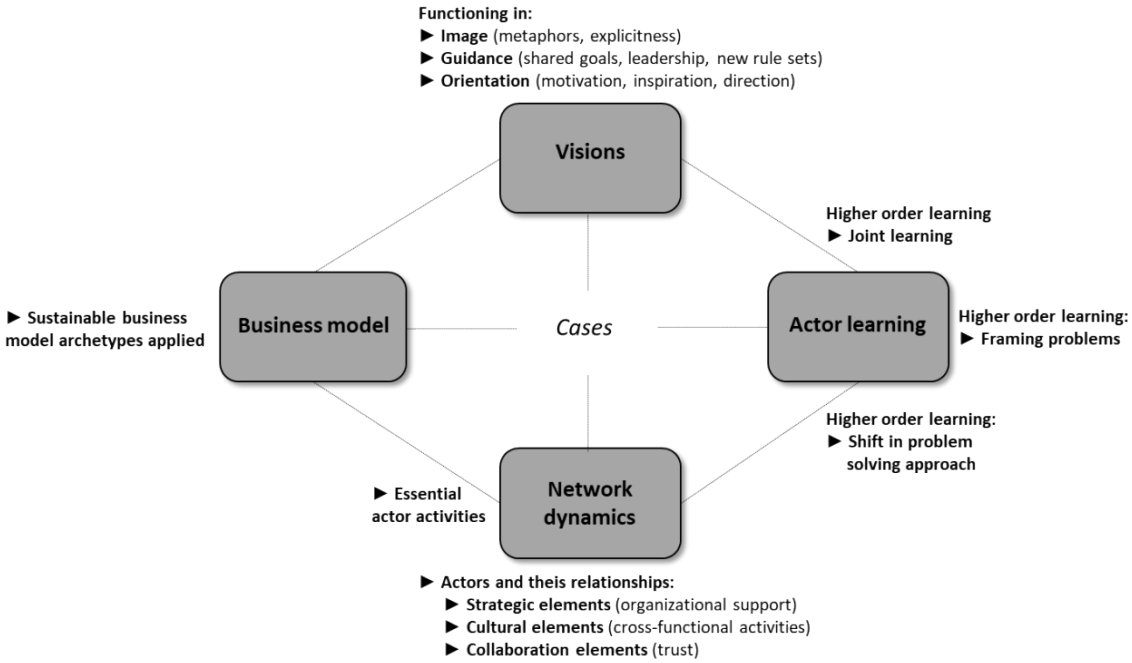

Figure 1 – Conceptual framework for CE in supply chain collaboration.

3. Methodology

3.1 Multiple case study

The conceptual framework in Figure 1 has been applied to the case studies by using the aspects of each building block for the analysis of the empirical data. The case study method was used because it allows for an integration of practice and theory, fitting the exploratory nature of this study (Zucker, 2009). An embedded multiple and exploratory case study method was applied (Yin, 2009). Embedded case studies allow for several units of analysis (Yin, 2009). The cases in this article are not only analyzed at the level of the entire pilot, but also at the level of actors and organizations and their collaboration in the building supply chain. Three cases in the Dutch building sector were selected, based on their position in the real estate lifecycle and their highly innovative character. The first case is *newly built* offices park 'Park 20|20' in Hoofddorp. The second case is the *renovation* of an existing offices complex of grid operator Alliander in Duiven. The third case is the Heerema head office building in Leiden, which is the first BREEAM certified *demolition* project in the Netherlands (BREEAM, 2013). The BREEAM methodology is a certification scheme for the environmental performance of buildings, comparable to the US based LEED certification program for green buildings. This scheme was applied to all selected cases and uses five levels: Pass, Good, Very Good, Excellent and Outstanding (BREEAM NL, 2015). As such, BREEAM provides options for sustainable solutions, but it does not (yet) rate the circularity of buildings. The three selected cases and some key characteristics are listed in Table 1.

Table 1 – Key specifications of the three selected cases.

Case:	Size	Program	Budget	BREEAM score	Starting date	Current status
Park 20|20	114.000 m^2	Park with 13 offices, café, greenhouse, pavilions	Investment value: €300 million	Excellent	Around 2000	7 out of 13 offices realized
Alliander office	25.700 m^2	Offices, labs, work-shops, meeting areas, restaurant	(Re)development: €26 million; installations: €10 million	Outstanding	Nov. 2010	Building in use; delivered in Nov. 2015
Heerema office	21.000 m^2	Offices, congress center, meeting space, gym, offshore simulation platform[1]	€60 million[1]	Very good for demolition; Excellent for building	Around 2011	Building in use; delivered in Sept. 2015

Cases were analyzed via document study (e.g. tender documents, BREEAM scores, articles) and a qualitative analysis of full transcripts from the interviews. Six stakeholders

[1] After the BREEAM certified demolition of the old Heerema building the new office was built at the same site. Table 1 shows the program of the new building. The budget includes both demolition and the new building.

were interviewed per case, resulting in eighteen interviews. Interviewees represent important actors involved in the selected circular building projects covering the entire supply chain like contractors, architects, developers, suppliers and clients. An overview of all the interviewees can be found in Table 2. The interview protocol (see Appendix A) included questions covering all aspects reflecting the building blocks of the conceptual framework. Moreover, the interview protocol asked all interviewees to reflect upon the relations between the different aspects in the building blocks as well as on CE in the building sector overall. A cross case analysis was done subsequently based on the document study and the outcomes of the interviews, structured alongside the aspects of the conceptual framework (see also Leising 2016).

Table 2 – Overview of interviews for the three cases.

	Case: Park20|20	**Case: Alliander office**	**Case: Heerema office**
Role interviewee 1:	Consultant/developer	Client/End user	Developer
Role interviewee 2:	Developer	Developer	Contractor
Role interviewee 3:	Architect	Consultant	Developing Management
Role interviewee 4:	General contractor	Interior Architect	Interior Architect
Role interviewee 5:	Installation advisor	Urbanist	Demolition
Role interviewee 6:	Materials certification	Architect	Client/End user

3.2 Development of the collaboration tool

Based on the outcomes of the case analysis, an empirically-based collaboration tool was developed providing guidelines for practitioners working on circular buildings. The tool development method is presented in Figure 2.

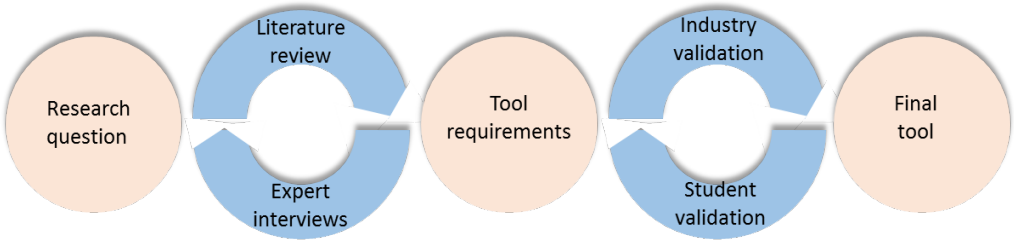

Figure 2 – Overview of tool development method (based on Geißdörfer et al., 2016; Bocken et al., 2011)

First, a research question was defined, followed by expert interviews and a literature review. In particular, literature on environmental management was used, showing a wide range of tools. Based on Byggeth and Hochschorner (2006), Baumann et al. (2002) and Bocken et al. (2011), analytical tools and organizing tools emerged as two major types of tools. Analytical tools include methods like lifecycle assessment, EcoDesign or the Dutch BREEAM score system (BREEAM NL, 2015). Organizing tools guide the organization of

collaboration and interaction for project and idea development and include interviewing and workshops to raise awareness or to discuss tools and strategies (Baumann et al., 2002). In addition, the interviewees (see Table 2) of the cases were queried about their experiences with tools. Next, tool requirements were formulated and this step was extended with additional literature study and an expert brainstorm (Appendix B). This resulted in an initial tool format, which was validated via sessions with industry and with Industrial Ecology students, resulting in the final collaboration tool.

4. Case study results

4.1 Park20|20: a 'newly built' office park

Park20|20 is an office area with closed cycles of water, waste and energy based on the C2C philosophy (McDonough and Braungart, 2002). The most innovative element is the inclusion of end-of-use options for buildings right from the start and the application of so-called 'resources passports' (Damen, 2012). The latter allows for tracking of materials and their corresponding residual value along the lifecycle of a building. Where possible, suppliers retain ownership of their materials, urging them to come up with solutions that can be disassembled easily to regain material value at the building's end-of-life. Examples are components such as the LED light system, solar panels and office equipment. C2C certified materials were used (McDonough and Braungart, 2002), which requires disassembly options of components and a scan for toxicity of products throughout their supply chain. Facility management is also important for the local closure of waste and water cycles.

The process for Park20|20 was initiated by developer Delta Development Group (DDG) in close collaboration with architect and C2C founder William McDonough. The project was led by a dedicated construction team that included a developer, an architect, a general contractor, a building installations advisor, interior designer(s) and an installation company. The 'construction team model' is a multidisciplinary collaboration model where participants collectively work on the preparation of a building project – while retaining their autonomy and responsibility (Chao-Duivis, 2012). It is a bilateral agreement between the commissioning company (in this case DDG) and the general contractor. The construction team model is regularly used in the Dutch building industry, but the scale and intensity at which this team collaborated – both in terms of disciplines involved and the project scale and duration – is novel. For each office building, a six weeks workshop series was held with its tenants and clients. The aim was not only to get to know clients and their requirements, but also to get clients acquainted with C2C principles. This is an important change in the building process, where a common language between client and construction team was established.

4.1.1 Case Analysis

The *vision* of Park20|20 is analyzed with regards to image, guidance and orientation (see Section 2). The visions' image includes strong metaphors, such as the building as a 'material bank', and the resource passport to keep track of materials. The material bank refers to the fact that materials are only temporarily stored in a building and will be reused again in the long term. The vision was made explicit through a vision booklet and a roadmap based on C2C principles in the project, allowing for discussion on the vision in both the building team and in workshops with clients. When looking at vision guidance, there are shared goals among supply chain partners and the vision includes new rule sets on ownership of building materials and components. The CEO of DDG and architect McDonough guided the vision in their role as vision champions (see quote 1; Table 3). The vision provided orientation, as it motivated, inspired and directed the construction team, for example to make certain material choices and look into implications for business models and investment strategies.

Learning at Park20|20 took place on all three aspects of higher order learning (Brown and Vergragt, 2008). Actors learned to frame the problem differently by extending the scope to include the end-of-life phase and reuse of materials (see quote 2; Table 3). They also learned that a multidisciplinary approach was needed that involves all supply chain partners right from the start to look for synergies and possibilities to innovate (see quote 3; Table 3). This new approach required more time and thus additional investments. Finally, actors also collectively learned about a new perspective on ownership of materials that are only temporarily stored in a building (see quotes 2 and 4; Table 3).

An essential activity in the *network dynamics* is the connecting role of the developer (DDG) who brought supply chain actors together (see also quote 3; Table 3) to search for innovative solutions in a broad construction team. Trust as a cultural element of the network dynamics (Barratt, 2004; Pomponi, 2015) was established by providing certainty to actors in the building team that they could participate in the next building to be developed. This led to a collaborative attitude. Moreover, the financially responsible parties for the project had collaborated before, facilitating trust. Cross-functional activities were analyzed that enable the exchange of information within or between organizations (as a collaboration elements cf. Barratt (2004)). At Park20|20 these activities took place both in normal project team meetings and in sounding board groups (see quote 5; Table 3). These additional sessions facilitated further information exchange. Organizational support (as a strategic element of the collaboration) was provided by developer DDG from the start, later also by other project partners.

The *business model innovation* strategy of Park20|20 focused on creating positive impacts (e.g. a healthier indoor climate could lead to happier more productive employees) and monetizing these impacts. This contrasts with the traditional sustainability approach of decreasing negative impacts. Six sustainable business model innovations could be identified:

- Create value from waste. This was achieved by design for disassembly, using the material bank concept and C2C materials, as well as closing the loops for water and waste;
- Deliver functionality without ownership, for instance by paying for the service of light instead of lamps and for the service of vertical transport instead of owning the elevator;
- Optimize material efficiency, for instance by reducing the spatial needs for clients of the buildings to be built;
- Substitute with renewables, in particular for energy;
- Repurpose for society by designing buildings with a healthy indoor climate to improve employee's productivity;
- Inclusive value creation, via alternative solutions for ownership in which suppliers own materials instead of the clients. For instance, the supplier retains ownership of the elevator and its materials.

Table 3 – Quotes from interviewees in the Park20|20 case (translated from Dutch).

Nr.	Quote	Role interviewee
1	*"Delta as a developer influenced by William McDonough can be regarded as the spiritual father of the vision for Park20|20."*	Installation advisor Park20|20
2	*"I learned a lot and became aware of our impact. We used to do projects based on what was out there but now you basically look at value creation. Are the materials you use recycled? And if you use plastics: are they recycled or virgin? So this is about awareness of the process."*	Installation advisor Park20|20
3	*"One makes a whole supply chain come together. Let's look at steel: from steel suppliers up until demolishers, and contractors and sub-contractors, the whole chain should be involved. It's remarkable that these parties don't get together themselves, but since we have initiated this, it happens. And only then you find out they don't know each other's business models. And the possibilities that emerge when you talk to each other and look at overlap of the different parties. (…) These are eye-openers (…) and it starts with communicating and connecting."*	Developer Park20|20
4	*"So we all started from scratch and learned together and grew together."*	Consultant Park20|20
5	*"The process is more complicated, but it will deliver so much more in the end (...) You see people getting enthusiastic when you get them out of their traditional thinking patterns by insisting that it is possible and delivers additional value."*	Developer Park20|20

4.2 The Alliander office: a 'renovation' case

Alliander is a Dutch energy grid operator which is dedicated to the transition to a sustainable society. Alliander wanted to create an iconic project and revealed high sustainability ambitions for the renovation of its office in Duiven. This resulted in a project in which five existing office buildings were transformed into one sustainable building. Materials were reused as much as possible. Take back management of the materials was put in place via 'resource passports'.

The process started in 2010 when Alliander redeveloped its real estate strategy and implemented a novel way of assigning a building project. Instead of specifying requirements, *needs* were the starting point allowing for innovation in both the building itself and the building process. Alliander summarized its needs and ambitions in a strategy document. This included a C2C building and a positive energy balance, as well as social ambitions, such as the creation of a pleasant working environment, a collaborative building process, and combining functions of the building with its surrounding area (e.g. combining work and leisure activities). This strategy document was used in the tender phase when Alliander asked consortia of building parties for a vision meeting their ambitions, instead of an initial design for the building. The winning consortium, led by the general contractor and the architect, turned the vision into an actual plan for the renovation. The most important *design characteristic* was the glass atrium connecting the five existing buildings. This atrium creates space and improves the energy performance of the building, because large parts of former outer walls would become inner walls. The atrium is made of a steel structure realized by a rollercoaster construction. Rollercoasters are pre-eminently built for disassembly, using as little material as possible. The process can be described as a co-creation between the consortium involving different building disciplines and Alliander as the client.

4.2.1 Case Analysis

The *vision* for the Alliander office was initiated by the client (Alliander) and it was developed together with the consortia who had responded to the tender and information requests. This open and collaborative search between the client (Alliander) and the consortia of building parties involved is innovative for the Dutch building sector (see quote 1; Table 4). The vision's image included the building as a moveable property as a key metaphor. This contrasts strongly to the current view on real estate as immovable, but it is quite similar to the material bank concept at Park20|20. The vision was made explicit in clear goals to achieve '80% circularity of materials' and a net energy positive building. Circularity of materials here refers to reusing materials. For instance, bricks and concrete from old buildings were

collected, newly coated and re-used. Also, scrap wood was saved from incineration to be re-used as façade material. In addition, doors and toilet bowls were reused, while bituminous roofing was returned to industry. It was processed into new roof covering and applied on the buildings' roofs. Vision guidance was present as goals were made explicit and were shared among supply chain partners. Moreover, the vision was guided by alternative rule sets for reusing wasted materials as well as a new design for the (tender) process. Lastly, with regard to vision orientation, it was found that the vision inspired and motivated both the entire consortium and the Alliander employees (see also quote 2; Table 4).

Learning in the Alliander case took place especially at the level of problem-solving solutions (cf Brown and Vergragt, 2008). Actors learned to broaden their scope in a new approach based on thinking in 'disciplines' instead of companies (see quote 3; Table 4), continuous dialogue and personal connections (see quote 1; Table 4). Identified essential disciplines included design, building, installations, maintenance and interior design that were all involved from the visioning phase in the very beginning of the project. Learning about framing the problem happened only partially among the consortium members, because the problem had already been defined in the earliest development phase by Alliander. In addition, building parties had already been selected in the tender process based on their commitment to the novel problem definition and the approaches to address the defined problem. Thus, joint higher order learning took mostly place before the pilot project, especially during the tendering process (see quote 4; Table 4).

Looking at the actor network, an essential activity in the *network dynamics* was the facilitation by the client. Alliander experimented with a new way to structure the building process based on collaboration and trust, which was new for the Dutch building sector. Trust as a cultural element was realized by Alliander in their open invitation to the building sector to support them in realizing their ambition. This vulnerability was novel for clients in the Dutch building sector. Another novelty was to keep the same players in the team from the first preparations until realization and even usage, leading to a greater degree of trust (see quote 5; Table 4). For the collaboration elements, Alliander facilitated cross-functional activities in its new process design where different working groups were assigned that combined expertise from Alliander employees and the consortium of building disciplines. In this way, information was optimally exchanged between the different organizations involved. While Alliander put also efforts in creating organizational support for the ambitions of the renovation project (see quote 6; Table 4), for instance by involving employees significantly.

The *business model innovation* strategy of this case focused on creating a circular building, aiming to achieve '80% circularity of materials' and a net energy positive building. Just like in the Park20|20 case six sustainable business model innovations could be identified:

- Create value from waste, for instance via high rates of reuse and recycling of materials and take back management via resources passports;
- Deliver functionality without ownership, by paying for the use of lighting and for other energy services;
- Adopting a stewardship role by contributing to biodiversity in the neighboring Natura 2000 area;
- Substitution with renewables; both the building process and the final building are completely powered by renewables;
- Encourage sufficiency, via outsourcing energy supply to incentivize low energy usage;
- Develop scale up solutions by experimentation with the new process design.

Table 4 – Quotes from interviewees in the Alliander case (translated from Dutch).

Nr.	Quote	Role interviewee
1	*"(Innovative was) the openness and the collaborative search. From the tendering phase onwards we used 'dialogue meetings' to collectively determine the end product."*	Interior architect Alliander office
2	*"When I emailed on Tuesday afternoon about a collective issue, we would have a meeting on Wednesday at the latest. Whether this was at 7AM or at 9PM: everyone attended."*	Client/end user Alliander office
3	*"You learn about the opportunities that collaboration with different disciplines provides. Traditionally you work 'after' each other. I never experienced this way of working so closely together before and with the right people. This is incredibly inspiring."*	Urbanist Alliander office
4	*"We did not directly [learn to frame problems in a different way] since we had the right people in this process that are open for each other's expertise."*	Urbanist Alliander office
5	*"(Keeping the same players in the team) greatly contributed to the fact that you can require others to respect their responsibilities and promises even after 2 years."*	Architect Alliander office
6	*"You can never create too much support. Getting a whole organization on the same page is very relevant. I also realized that creating something tangible inspired people in the organization. That is the best organization development trajectory."*	Consultant in the project around the Alliander office

4.3 Heerema office: a 'demolition' case

The Heerema building in Leiden is the head office of Heerema (HMC), a marine contractor in the international offshore oil and gas industry. The project for their new head office started in 2011 when HMC looked for a new office space, due to business growth. Before realizing the new office building, the old abandoned HMC office building at the site was demolished, certified via the first BREEAM demolition certificate. Developer DDG (also the initiator in the Park20|20 case) saw an opportunity by demolishing HMC's old office building as the first Dutch pilot project in the BREEAM demolition certification scheme. In

this case it meant that during the demolition stage all material streams were reported and separated into twenty different categories to support reuse of those materials. The process organization was based on a construction team model, just like in the Park20|20 case. The Heerema case was different from the other two cases because it focused on closing the loop at the end of the lifetime of the building, and not on realizing circularity during the entire building's lifetime. The development of the new office is not part of this case analysis.

4.3.1 Case Analysis

The *vision* for the sustainable demolition part of this case was initiated by the developer (DGG, the lead actor in the Park20|20 case). Looking at the vision's image, no specific metaphors were used. The vision was also not made explicit in text nor through images (see quote 1; Table 5). When looking at vision guidance, the goal of achieving the BREEAM certificate for the demolition was shared among the actors involved. Moreover, for the vision's guidance, some authoritative aspects are present since DDG was able to convince HMC to focus on sustainability (see quote 2; Table 5). The vision does not refer to alternative rule sets, as it was mainly based on current building practices including BREEAM rules. Lastly, for the orientation function of the vision, motivation was present in the construction team to achieve the first BREEAM demolition certificate (see quote 3; Table 6), but no clear direction and guidance was provided by the vision, resulting in a less ambitious project compared to the other two cases.

In this case *learning* mainly took place at the level of problem solving approaches, for instance when the construction team learned about the benefits of the collaborative approach (see quote 4; Table 5). Some team members mentioned that improvement was still possible by involving all actors even earlier on in the process. Learning about framing the problem did not occur and neither did joint learning. The project did not challenge major mental frames of actors, as stated by the majority of interviewees in this case.

The most relevant essential activity in the *network dynamics* is the intermediating role of the developer between the client and the construction team. For the cultural elements, trust was clearly present and was stimulated by showing and explaining each other's 'world' (see also quote 5; Table 5) and by several meetings to discuss the process. The project did not facilitate the collaboration element of cross-functional activities, which was due to the application of a rather traditional functional separation in the process design. The strategic element of creating internal support was only marginally supported within HMC compared the other two cases.

With regard to the *business model innovation* strategies, the Heerema case had a focus on contributing to the demolition sector and providing a new building that fits the needs of its users for the coming 20 years (at least). Only one sustainable business model innovation was identified in this case, namely creating value from waste via the separation of demolition waste in 20 different streams that could be reused afterwards.

Table 5 – Quotes from interviewees in the Heerema case (translated from Dutch).

Nr.	Quote	Role interviewee
1	*"We never saw or made a real vision on paper."*	Client Heerema head office
2	*"Acting sustainably was less important (for the client). And we were able to force this by showing the benefits of a green environment. (...) It was for instance found that employees who have a view on a green roof when drinking their coffee are 30-40% more concentrated afterwards than employees overlooking a regular roof."*	Developer Heerema head office
3	*"From a contract perspective, it could mean a financial cut down if we would not reach the targets, but since we agreed to go for those four (BREEAM) stars we just did it. So just go for it and keep your promise."*	Demolition Heerema head office
4	*"I realized it helps to think about it (the BREEAM certificate): you need each other. So collaboration is certainly needed."*	Interior architect Heerema head office
5	*"They (HMC) know about ships, but not so much about buildings. So we (Delta Development Group) were taken to their ships and we showed them our buildings."*	Developer Heerema head office

4.4 Cross case comparison

The results of the cases on the aspects for each building block in the conceptual framework for CE in supply chain collaboration are summarized in Table 6. It shows whether the identified aspects in the conceptual framework were present in each case.

Table 6 – Comparison of CE in supply chain collaboration for the three cases.

	Park20|20	**Alliander office**	**Heerema office**
Visions			
Vision image			
• Metaphors	✓	✓	–
• Explicitness	✓	✓	–
Vision guidance			
• Shared goals	✓	✓	Partly
• Leadership	✓	✓	Partly
• New rule sets	✓	✓	–
Vision orientation			
• Motivation	✓	✓	✓
• Inspiration	✓	✓	–
• Direction	✓	✓	–
Learning			
Framing the problem	✓	Partly	–
Problem solving approach	✓	✓	✓

Joint learning	✓	Partly	–
Network dynamics			
Essential activity	✓	✓	✓
Strategic elements Organizational support	✓	✓	–
Collaboration elements Cross-functional activities	✓	✓	–
Cultural elements Trust	✓	✓	✓
Business model innovations			
• Optimize mat./en. efficiency	✓	–	–
• Create value from waste	✓	✓	✓
• Substitute with renewables	✓	✓	–
• Deliver functionality	✓	✓	–
• Adopt a stewardship role	–	✓	–
• Encourage sufficiency	–	✓	–
• Inclusive value creation	✓	–	–
• Repurpose for society	✓	–	–
• Develop scale-up solutions	–	✓	–

Table 6 shows that the Park20|20 case and the Alliander case performed both well on the aspects of the framework, while in the Heerema case only a few aspects could be identified. The Park20|20 case performs better than the Alliander case for *learning* aspects. Considerable learning took place in the Alliander case, but most of the learning related to *reframing* the problem and took place *before* the start of the renovation project, and hardly during the project.

For the Heerema case, only the motivational aspect and partly shared goals and leadership could be identified as part of the vision aspects. This confirms that the Heerema case is less ambitious compared to the other two cases, both technically and process-wise. In addition, learning in the Heerema case took only place at the level of problem solving solutions, leading to less learning compared to the other two cases. For *network dynamics*, Table 6 shows that the Heerema case scored well on the cultural elements and essential activities, but trust (collaboration element) and organizational support (cultural element) were considerably less present compared to the other two cases. Finally, the Park20|20 and Alliander cases scored both well on *business model* innovations, each demonstrating evidence of six types, while in the HMC case only one novel business model innovation type could be identified.

5. Development of a collaboration tool

Based on the tool development method shown in Figure 2, this section describes the development of a collaboration tool to support CE in the building sector. The literature

review in the first iteration round showed two main tool categories: analytical tools and organizational tools. The interviews showed that analytical tools are widely available (for example Life Cycle Analysis methods, sustainable product checklists, certification schemes such as BREEAM), while organizational tools are less developed. Therefore, it was decided to focus on the organizational tool category. The tool requirements based on the first iteration round can be found in Appendix B.

During the validation sessions in the second iteration cycle, the value of the tool requirements and the initial tool format were critically discussed and suggestions for improvement (e.g., additional explanation of some of the main tasks in the tool) were added. This resulted in the final collaboration tool as presented in Figure 3, consisting of five phases. The tool takes the perspective of the initiating party (i.e., clients that might also be end users) and the phases are described as follows:

- **Phase 1: Preparation & Vision Development.** CE in supply chain collaboration starts with clients asking different questions. Instead of developing specified requirements for a building project, a vision for both the product and the collective process is created. This requires leadership from clients and organizational support to through new collaboration processes of co-creation between clients and supply chain partners.
- **Phase 2**: **Involve Market & Supply Chain**. In this phase, the (multidisciplinary) team who design, build and maintain the building is selected. This builds on required disciplines needed for the project instead of specific firms. In this way, new types of collaboration can emerge between disciplines that otherwise would not have cooperated. This stimulates innovation and assures that parties are involved that create value for the project and supply chain as a whole instead of just doing their own regular activities without considering the overall lifecycle of the building. Personal connections are key, which can be facilitated by the client or an appointed facilitator and are needed to realize the established vision and ambition in the project.
- **Phase 3: Process Design & Collaboration.** Collaboration between supply chain partners is formalized in this phase using non-traditional contracts in which collective aims are key instead of detailed specifications and distributed responsibilities. Trust is again an essential factor in this phase, as in these types of contracts supply chain partners need certainty about their involvement in the next phase. This phase also starts with the technical support of the collaboration. This includes Building Integrated Modelling (BIM), which is software that allows users to model the building in an integral way, revealing all the material streams in the building in one data set.

- **Phase 4: Business Model & Implementation.** In this phase, the building activities take place. These activities are linked to investments, relating this phase to the development of new business models. Business models should include a (financial) incentive for the collective aim of creating a circular building as opposed to the current situation (in the Dutch building sector) of fragmented incentives to make the highest margins based on one's own services.
- **Phase 5: Usage & Prepare for next use.** This phase assures that material value is maintained via reuse, repair or recycling of building materials. Two different types of materials and components can be discerned: those with a short lifecycle (e.g. office furniture and supplies, and sometimes the spaces and services) and those with a long lifecycle (e.g. site, structure and facade of the building). Suppliers can take responsibility for short-lived products via take back schemes (e.g. via leasing products or providing a buy back guarantee). For long-lived products, a 'material market place' can be established. Such an (online) market place for second hand materials and components brings together supply and demand and in this way the cycle can be closed by reusing these resources in a new project, for which the tool can be used again starting with Phase 1.

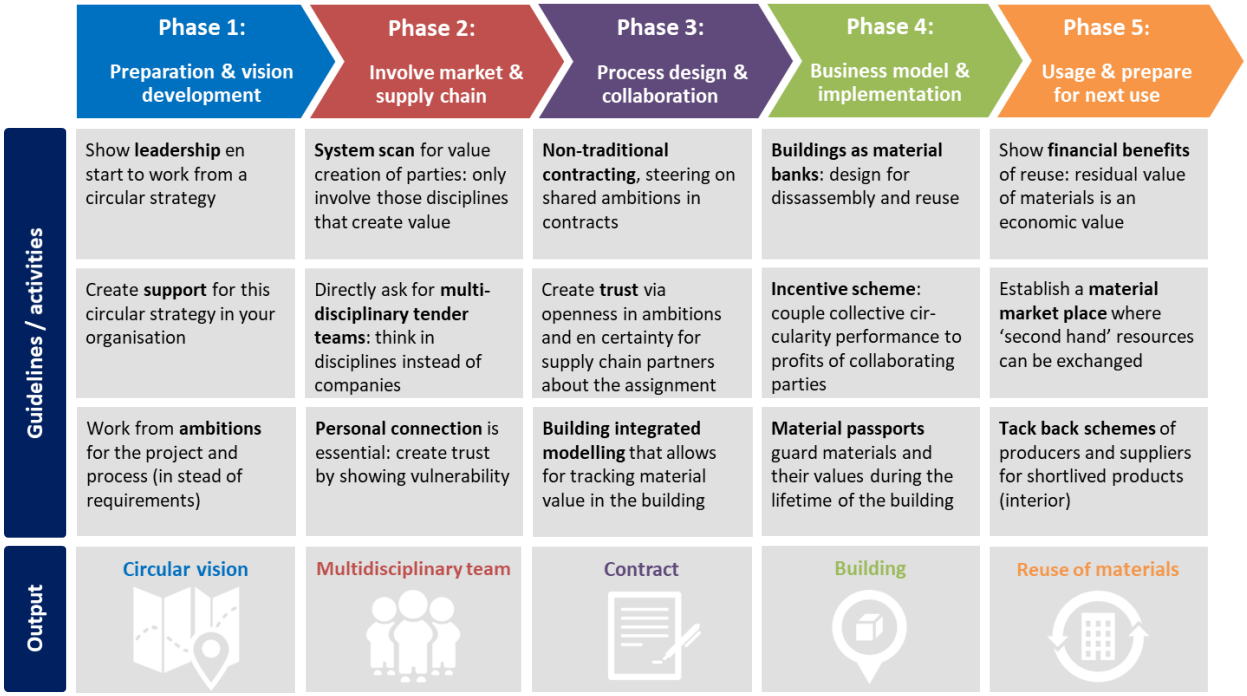

Figure 3 – Collaboration tool for CE in the building sector.

6. Conclusion, discussion and recommendations

6.1 Conclusions

This article has investigated how new ways of supply chain collaboration can contribute to the transition to a circular building sector in the Netherlands. The following conclusions can be drawn.

Firstly, CE in supply chain collaboration starts with *vision development*. The cases show that clients have a key role in redefining their requirements based on needs instead of specified requirements. Vision development can contribute to supply chain collaboration by involving stakeholders with relevant knowledge to refine the client's vision and ambition *together*. This supports the evidence for the coordinating and guiding role of visions in the vision literature (Borup et al., 2006; Quist et al., 2011).

Secondly, higher order actor *learning* is essential to embed new collaborative approaches amongst supply chain partners. This relates to the pioneering phase of CE in the building sector: actors need to learn to broaden their scope to include end-of-life options for a building. They also need to absorb a new multidisciplinary way of problem solving where actors can be held responsible by others for their tasks and deliverables. In addition, new perspectives and rule-sets have to be established. For circular buildings, this entails a new perspective on ownership of "materials that are only temporarily stored in a building". These findings confirm the relevance of higher order learning in change processes and transitions to sustainability (Brown et al., 2003; Quist, 2007).

Thirdly, an essential activity in the network dynamics is facilitating supply chain collaboration by bringing all partners together – from suppliers to designers, demolishers and waste companies. This calls for trust between supply chain partners, especially among the ones that are normally not involved in the design process. Trust can be created by (i) proactively asking partners for support and expertise, (ii) providing certainty for upcoming assignments, and (iii) openly discussing the process, instead of only the content. These are innovative aspects for the Dutch building sector. Our findings also show the relevance of investigating cultural aspects in both industrial networks and supply chain collaboration.

Fourthly, new types of sustainable business models have been identified in circular building pilots. These can be seen as important enablers for the implementation of collective approaches for supply chain collaboration in closing and slowing resource loops. In these business models, circular and sustainable value creation are actively sought. As such, responsibilities of supply chain partners need to extend to the entire supply chain, during the complete lifetime of a building, including the end-of-life stage through new ownership

models. Such innovative ownership models have been described in the literature on sustainable and circular business models (e.g. Bocken et al., 2016), but the embedding in supply chains (instead of a single organization) has not been shown before.

Fifthly, the cases show that a new process design is required in which a variety of disciplines along the supply chain is integrated upfront for developing the vision in co-creation with clients.

Finally, based on the findings and additional research, a collaboration tool for practitioners and professionals has been developed. This tool combines the findings in an overview with five phases from vision development to reuse of materials. The three cases and the developed collaboration tool can make significant contributions to a transition to a circular building sector, as they include best practices and provide inspiring examples to replicate and to improve further. The tool can support new pilots and help actors explore ways to move towards a circular building sector. The tool can also be used by policymakers interested in circular supply chain and business model innovation.

6.2 Discussion

In this study, we sought to conceptualize the organizational aspects of supply chain collaboration for CE in the building sector. We contribute to the sparse literature on circular buildings and long-lived goods. Moreover, we explore the emerging topic of circular value chain collaboration, by connecting and integrating the fields of sustainable supply chain management and the CE.

By investigating the three cases using the developed framework, it became clear that two out of the three cases scored well on CE in supply chain collaboration (the Park20|20 case and the Alliander case). Although in the Heerema case sophisticated waste management (via BREEAM certification guidelines) was put in place, this did not guarantee that construction waste was reused or that new material ownership models (e.g. where buildings function as a ‘material bank’) were applied in the new building. This shows a limitation of current certification schemes. It also points to the importance of the visioning phase, of getting all supply chain partners involved in the early project phases and of creating personal connections and trust in the team. This study also shows that CE in supply chain collaboration depends on personal ambitions – when partners lack high ambitions, CE in supply chain collaboration is very difficult to establish. The Heerema case shows that a focus solely on the demolition process is too limited. For a circular project, reuse of demolished building components in a (renovation) project need to be included in the ambitions and the vision.

The conceptual framework for CE in supply chain collaboration developed in this research allowed for a clear picture of the three cases. However, it is predominantly descriptive, whereas further development and refinement may shed more light on how the four building blocks relate to each other, whether there are patterns and mechanisms, and whether levels of performance can be defined. The latter would also allow for comparing the cases in a more systematic way. It should also be noted that only three cases have been studied. The results should be considered as tentative. It would be beneficial to extend the number of cases not only to more circular buildings, but also to other domains where visions and transitions are important. Furthermore, the business models have been mapped, whereas more in-depth follow-up work could enhance our understanding of circular business models in the built environment. For instance, stakeholder collaboration is seen as essential for sustainable business model innovation (Bocken et al., 2016), as well as for developing circular value chains. Moreover, incentives can guard and ground collaboration in the business model (Kraaijenhagen et al., 2016; Leising, 2016) by deliberately incorporating (financial) interests of all stakeholders towards the collective goal of a circular building. This means that financial rewards are connected to the achievement of the collective goal, so that actors involved need each other. This could help secure supply chain collaboration – even over longer time frames. This might not be highly novel to practitioners in other sectors (e.g. Kraaijenhagen et al. 2016), but in the (Dutch) building sector it could considerably boost circular practices.

6.3 Recommendations

6.3.1 Recommendations for further research

A first research recommendation is related to the further development of the conceptual framework. The relationships between the different building blocks can be deepened and the building blocks can be further elaborated. For instance, the business model conceptualization and the cultural elements can be further refined. Recently, business model archetypes were developed for circularity (Bocken et al., 2016) and future work might take into account specific archetypes for circularity rather than the broader field of sustainability. The interactions between different business models and how CE in supply chain collaboration differs from mainstream business models could also be relevant for follow-up research, as well as to look more in-depth into the business model innovations identified in the cases. Furthermore, transition theory (Grin et al., 2010) can be integrated in the framework to allow for the development of transition pathways for circular practices in a

broader part of society, while also backcasting frameworks could contribute here (e.g. Quist and Vergragt, 2006).

6.3.2 Recommendations for practitioners

A major recommendation to practitioners - in particular initiators of building projects - is to use and further develop the collaboration tool. This includes that circular buildings start with vision development and in this phase initiators should aim for 'circularity' in the end product and pursue a collaborative process. It is recommended to think in ambitions and needs instead of (over)specified requirements in this visioning phase. To sharpen visions and ambitions collectively, from the start, supply chain partners could be invited to a co-creative process. It is also recommended to facilitate the collaboration by 'connecting' disparate disciplines; using their perspectives and aiming for integral solutions. Innovative contracting could be applied as a next step based on collective aims instead of specifications and externalized responsibilities. To create circular supply chains and support reuse of building materials, a final recommendation is to adopt take back schemes of suppliers for short-lived products and to establish a material market place for long-lived products, components and resources that can easily be exchanged between demolition sites and (re)development projects.

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Appendix A – Interview protocol

Interview Goals

Gain insights in in how actors deal with circular building projects, what they experienced working on a circular building project, how collaboration and the business model functioned and what they see for the future of circular buildings.

Sub goals: gain insights in:

- Motivation to participate in the particular project.
- General experiences during the project.
- Role and influence of visions during the project.
- Actor learning processes and reflection in the specific project and their influence on further diffusion of circular building practices.
- The composition of the network/supply chain in the specific building project, roles and collaboration of the different parties and actors involved.
- The innovative aspects of the business model(s) applied in the building project.
- Drivers and barriers for the particular project and for Circular Economy in the building sector.

Interview Questions

1. Exploring the topic of the Circular Economy:
    a. What is your definition of Circular Economy? And how would you define Circular Economy in the building sector?
    b. How are you (or is your company) working on circularity within the building sector? What activities/projects do you do around circularity?
2. Exploring the particular project/case study:
    a. How are you and your company involved in this project?
    b. Why are you involved in this project?
    c. What are your most important experiences during this project?
    d. What was the most innovative part within this project?
3. Visions of the future:
    a. Was the project based upon a vision? What does this vision contain/what is the aim?
    b. How was this vision developed?
    c. To what extent was this vision shared by everyone /did other interpretations arise?
    d. How is this developed vision related to your personal vision/ideas (around sustainability/circular economy)?
    e. How is this developed vision related to the vision/ideas of your company (around sustainability/circular economy)?
    f. How does this vision contribute to the practical development of circular economy in the building sector?
4. Actor learning
    a. What did you personally and as a company learn from participation in this project?
    b. What did others (involved) learn from the project according to you and what was learned collectively within the project team?
    c. How did you originally perceive the projects' problem (e.g. from a technical or management background) and did you change your view during the project?
    d. Were interpretations within the team adjusted? For instance about the importance of sustainability, adding value, norms and values?

e. What would you do different the next time and how would you do that?
f. How were learning processes organized within this project? Did you work together on the vision?
g. What methods and tools were used within this project? What methods did work and why? What methods did you miss?
h. What are the most important lessons for others working on the implementation of the Circular Economy?

5. Network dynamics:
    a. Who were involved within the project (partners) what were their activities and what roles did they play (both formal and informal)?
    b. What were your main activities – both individual and at company level – within this project and during which activities you needed other parties?
    c. Who were involved outside of the direct project team (advisory, education team) and how?
    d. How would you position your company within this project with regard to means like (entrance to) knowledge, employees and financial means?
    e. What parties/people were essential within this project and why?
    f. What did the project organization look like? How did you collaborate?
    g. What about trust? Was this present and if so, how was this established?
    h. How did you communicate? How did you deal with (confidential) information? How did you deal with shared risks?
    i. What was different within the contracts with partners (other than standard)? Did they include certain performance standards for all parties to improve the collective result?
    j. What was the most innovative element in the collaboration during the project?
6. Business model innovation:
    a. Could you describe the business model within this project? Seen from the Circular Economy, what was the most important value? (e.g. additional value creation for the environment/society and if so, how was this established?)
    b. What was different from this business model compared to a standard business model?
        i. What value is created for whom / what is the value proposition?
        ii. How is this value created/ what activities/technologies and partners are needed?
        iii. How is revenue generated for you and involved partners and how do you divide the revenue?
    c. Is collaboration an explicit part of the business model? If so, how?
    d. How could the value proposition be improved? At what aspects (social, ecological, economic) did the project miss value creation?
7. Check framework:
   When looking at the different topics (visions, actor learning, network dynamics, business model innovation): what aspects are most influential? Could you place them in a sequence from most to less influential?
8. Scaling up Circular Economy within the building sector:
    a. What is needed to scale up these kinds of projects successfully?
    b. What activities are needed and who has to execute these?
    c. What are drivers/barriers for scaling up this project?
    d. How does this contribute to a transition of the building sector to a circular economy?

Appendix B – Tool requirements

The requirements for the tool are derived from literature and interviews with practitioners in the three cases studied in this paper. The following table reveals these requirements and their origins:

Tool requirement:	**Requirement based on:**
1. The tool should be based on a lifecycle perspective	Byggeth & Hochschorner (2006): p. 1425-1426
2. The tool should be based on a qualitative approach	Byggeth & Hochschorner (2006): p. 1425-1426*
3. The tool should give concrete descriptions	Byggeth & Hochschorner (2006): p. 1425-1426*
4. The tool should support the collaboration process	Weiseth et al. (2006): p.241
5. The tool should cover the technicalities of the development of a circular building as such	Baumann et al. (2002): p. 410 **
6. The tool should deal with the building development process in a company context, relating it to business strategy / management	Baumann et al. (2002): p. 410 **
7. The tool should deal with the building development process in the building supply chain (interaction with e.g. suppliers, clients)	Baumann et al. (2002): p. 410 **
8. The tool should deal with the building development related to policy processes	Baumann et al. (2002): p. 410 **
9. The tool should be simple to use and not time demanding	Interviews, e.g.: *"Keep it simple and short. Like a love letter in primary school."* (Developer Alliander office)
10. The tool should trigger businesses to change current (linear) practices and stimulate innovation	Interviews, e.g.: *"What we did was that we stick to innovation"* (Developer Park20|20)
11. The tool should be adaptable to different sectors, businesses or organizations and their needs	Interviews, e.g.: *"Usually, stakes of different organizations, businesses or even sectors are not taken into account."* (Consultant Alliander office)
12. The tool should contain only a few main steps or phases	Interviews, e.g.: *"Keep it practical. Stick to only a few main steps to make it efficient instead of very specialized."* (Urbanist Alliander office).

Tool requirements and their origins.

* Byggeth and Hochschorner (2006) present a choice between a quantitative or qualitative approach and a choice between concrete or general prescriptions. Since in this paper only qualitative data is used, this is adapted to a requirement for a qualitative approach. Moreover a choice for concrete descriptions was made since this is what is missing in developing CE.

** Baumann et al. (2002) developed these requirements for environmental product development. The requirements presented here are adapted to circular building development.