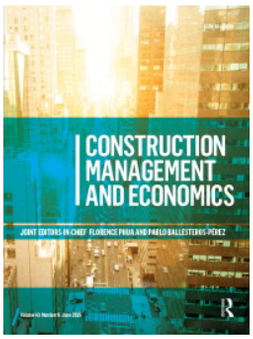

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Circular building hubs as intermediate step for the transition towards a circular economy

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ABSTRACT

Despite growing government and market interest to use Circular Building Hubs for reusing construction components, few academic articles have been written about them. We know little about the potential of hubs to answer to the challenges of reuse in the present and future, and their potential to drive systemic changes towards a circular economy. Using various qualitative research methods, this article aims to respond to this research gap by applying social practice theory and the multilevel perspective on past and future practice reconfigurations within the system-of-practices in which these hubs reside. Results show that within hubs reconfiguration from demolition to deconstruction and repair and refurbishment practices have been developed. However, selling components remains challenging, and procurement for reuse and design skill remain underdeveloped. Practitioners expect the system-of-practices to professionalize in the coming years, resulting in market growth for secondary components. Long term, practitioners expect hubs to shrink or disappear because the balance between supply and demand will be controlled digitally. Hubs are therefore a driver for the transition, but only as intermediate step, not as solution for a circular economy. This article is particularly interesting for academics studying CE and transitions, and policy makers interested in developing Circular Building Hubs.

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Social practice theory; transitions; circular building hubs; circular economy; reconfiguration

Introduction

The architecture, engineering, and construction (AEC) sector is one of the most polluting sectors, responsible for around 37% of global CO2 emissions and energy consumption (Unep 2022), and 50% of global material use (De Wit *et al*. 2018). Implementation of a circular economy (CE) is by many perceived as a possible answer. For building design, CE can take form in seven design strategies (Cb'2323 2023): (1) design for prevention, (2) design for quality and maintenance, (3) design for adaptability, (4) design for disassembly and reusability, (5) design with existing building (parts), (6) design with secondary resources, and (7) design with renewable resources. Of these, design with secondary resources proves especially difficult to implement (Nußholz *et al*. 2019, Andersson and Buser 2022, Hanemaaijer *et al*. 2023, Van Uden *et al*. 2024a).

Design with secondary resources can entail recycling, refurbishing, repair, and reuse (Desing *et al*. 2020). Recycling of mineral materials is already quite common (e.g. in the Netherlands around a third of total mineral use), but this mostly relates to downcycling of concrete and bricks. The strategies of refurbish, repair, and reuse are considered more local and sustainable (Ghisellini *et al*. 2016). Yet, markets for these products are small or absent (Munaro *et al*. 2020), the quality of building components is often low (Adams et al. 2017, Ababio and Lu 2023), data of existing buildings are missing (Koutamanis *et al*. 2018, Van Den Berg *et al*. 2021), investment costs are high (Ababio and Lu 2023), and guarantees are often difficult to give (Kooter *et al*. 2021). Despite EU-wide increased taxes on landfills, reuse and recycling rates have not gone up significantly (Sáez and Osmani 2019), which is often explained by a missing logistical structure for reuse (e.g. Nußholz *et al*. 2019), hesitant behavior regarding procurement (Adams *et al*. 2017), and lacking design skills (Gerding *et al*. 2021, Van Den Berg *et al*. 2024). In recent years, in response to this problem in the Netherlands, visions of Circular Building Hubs (CBHs) emerged in municipal and

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provincial documents (e.g. Amsterdam 2019) and several CBHs popped up.

Various definitions of CBHs exist (Tsui *et al*. 2023), but it is here defined according to the practices they enable: physical locations where construction and demolition waste in the form of building components from disassembling sites are transported to, sorted, inspected, prepared, repaired, refurbished, remanufactured, and temporarily stored, so they can be reused or repurposed later as secondary building components in construction projects. This makes them different from industrial clusters that focus on recycling, craft centers that focus on business-to-consumer sales, and virgin material hubs that have a purely logistical function. In practice, many terms describe something similar to CBHs, such as urban mining facilities or construction waste marketplaces, although the latter often concerns recycling more than reuse (Caldera *et al*. 2020). CBHs are not necessarily new, but renewed interest in these hubs partly stems from their circular potential (e.g. Amsterdam 2019), expected regulations regarding reuse of construction demolition waste (Deloitte 2017), employment possibilities (Van Buren *et al*. 2016), and uncertainties regarding global supply chains, as became evident during the Covid-19 lockdowns (Wuyts *et al*. 2020, Dumée 2022). These hubs would offer greater economic independence.

Some challenges for CBHs are discussed in non-academic literature. Van Hoogdalem (2022) for instance mentions problems relating to upscaling, shared ownership, and difficulties of demanding hub use in tenders. Also the lack of data structures that accompanies the physical structures is often mentioned (Metabolic, Amsterdam & Copper8 n.d.).

So far, despite their emerging popularity, CBHs have not been studied well in academic literature. Recent studies have mostly focused on spatial parameters to choose optimal locations (e.g. Tsui *et al*. 2023, Yang *et al*. 2023). However, also more fundamental, we know little about the changes in practices of hubs that enable them to answer to the challenges of reuse in the present and the expected changes in practices in the future that might change this. To answer these challenges, hubs must be able to compete against the practices of virgin supply chains. This requires a business case that can challenge virgin resources, but also practice development, not just in CBHs, but throughout the supply chain.

To research this, we made use of both Social Practice Theory (SPT) and the multi-level perspective (MLP). SPT is an often used lens to study changing practices (Schatzki *et al*. 2001, Shove *et al*. 2012). Practices are interpreted here as a type of behaving and understanding that appears at different locales, in different times, by different bodies and minds (Reckwitz 2002). In recent years this lens is also applied more often on systemic scales in studies of systems-of-practices (Watson 2012, Spaargaren *et al*. 2016). Contrasting many other cultural theories, SPT explicitly focuses on the materials that help (re)produce practices (Shove *et al*. 2012), which is helpful in studying CBHs that are shaped by the materials they concern. Unsurprisingly, SPT has often been used for transition research, because in the end every transition is a transition in practices (Watson 2012). It has also been used as such in the AEC sector (e.g. Van Den Berg *et al*. 2021, Eikelenboom and Van Marrewijk 2023, Van Uden *et al*. 2024a). The MLP is also an often used lens to study transitions (Köhler *et al*. 2019). We use it here to better understand CBHs role in challenging virgin resource chains and to give an explanation of the change that is and is not happening in their alternative supply chain. In recent years, the combination of these approaches has been used for similar purposes (Van Uden *et al*. 2024b), also in the AEC sector (e.g. Van Uden *et al*. 2024a). The combination has proven especially useful for studying reconfigurations, changes in practice that contain both new and old elements (Van Uden *et al*. 2024b).

With this theoretical background, the aim of this research is to better understand reconfigurations in practices regarding the system in which CBHs reside. For this, we want to understand (1) recent reconfigurations in practices regarding CBHs and other practices in the system in which they reside (e.g. also including design and procurement), and (2) future reconfigurations practitioners deem likely for practices regarding CBHs and the system in which they reside. These aims require a scope that goes beyond a single practice, but instead concern many interlinked practices that together form the whole system they are part of, that is the system-of-practices that makes up their supply chain. This leads to the following research question:

Which reconfigurations have taken place in the system-of-practices in which circular building hubs reside regarding reuse of secondary building components and how is it deemed likely to transition in the future?

This question will be researched in the case of the system of circular hubs in the Netherlands. We take a systemic perspective, as changes in this transition or the lack thereof are the result of collaborations of multiple actors (Wamelink and Heintz 2015, Kooter *et al*. 2021, Coenen *et al*. 2023). This means that this research concerns not just practices on the grounds of

CBHs (i.e. storage, repair, and refurbishment practices), but the whole supply chain of which they are a part.

This article is built up as follows. First, the operationalization of SPT and MLP is discussed. Second, we elaborate further on the mixed qualitative research methods for this study. Third, the results are discussed, focusing on past reconfigurations, and envisioned future reconfigurations. Fourth, we discuss the results in the context of earlier research on reuse of building components, logistical hubs, and niche protection. And lastly, we elaborate on the research question and conclude that CBHs should be perceived as an intermediate step, in this transition and not as ultimate solution for a CE.

Practices in transition

We understand changes in the system-of-practices, such as the change towards CE in the AEC sector, as a transition, which comprises structural changes of a socio-technical system (Köhler *et al*. 2019). They are complex, comprising many different actors (Geels 2005), practices (De Haan and Rotmans 2011), aspects (Heurkens and Dąbrowski 2020), such as laws and regulations, market developments (De Haan and Rotmans 2011), and visions of directions (Desing *et al*. 2020, Kooter *et al*. 2021). They are path-dependent and progress non-linearly (Wittmayer and Loorbach 2016).

An often used lens to study transitions is the multi-level perspective (MLP) (Köhler *et al*. 2019), which we use here to give context for this transition and additional explanation for early change development. In the MLP transitions are understood as a result of interactions between different levels of structuration (Geels 2011): the niche (the locus of radical innovation), the regime (the locus of established rules that stabilize the existing system, and an exogenous socio-technical landscape (Geels 2011). We can interpret the landscape as climate change and macro ambitions (e.g. the Sustainable Development Goals developed by the United Nations) to counter this. This landscape puts pressure on the regime (e.g. rules and regulations of countries and unwritten rules of how to conduct business), which in turn allows niches (e.g. the quickly changing rules that govern practices in CBHs) to challenge the regime. The regime is not a single coherent whole, but a combination of stabilized rules regarding markets and user preferences, science, culture, technology, policy, and industry. Regimes are relatively stable, which is enforced by institutional, psychological, and organizational barriers for innovation (Brown and Vergragt 2008, Van Bueren and Broekhans 2013), such as formal regulations, and long-lasting relationships between suppliers and clients. Contrastingly, niches are constantly evolving (Schot and Geels 2008). Niches gain momentum when transition directions become more apparent and stable, when learnings have resulted in more stable configurations of elements, and the networks of involved actors have grown significantly. When niches and regimes interact, they often merge together, resulting in a stretched regime (Laakso *et al*. 2021). In this merging, regimes often prove not to be static systems, but contain dynamics of their own (Smith 2007, Laakso *et al*. 2021). Niches are often portrayed as technological innovations, but they can also be predominantly market and/or logistical changes (Raven 2006). Practices around CBHs can therefore be conceptualized as niches, contrasting the regime of virgin building component suppliers, which both are embedded in a system of systems with markets, science, cultures, technologies, policies, and industry.

Even though CBHs have often been developed from existing regime demolition practices, in their current form they are often "companies in companies", similar to R&D programs (Schot and Geels 2008). Whether something is niche or regime should therefore not be determined by the actor, but by the rules that guide the performance of practices. This take aligns with the neo-institutional origins of the MLP (Geels 2020). Niches are often built up in a protected environment, so they can develop without having to compete with the regime immediately (Smith and Raven 2012). Protection can include shielding (holding off selection pressures), nurturing (supporting innovation), and empowerment (making niches competitive), all of which can influence each other. We use these notions of niche protection in the discussion section to understand which elements allow the system-of-practices in which CBHs reside to change. Scholars anticipate that the transition towards a circular economy in the AEC sector makes the regime change in such a way that the new regime contains both elements from the old regime and niches, which is called reconfiguration (Kooter *et al*. 2021, Ruijter *et al*. 2021, Van Uden *et al*. 2024a). This reconfiguration takes place in the form of changes within practices throughout the system and requires practices to continuously re-align with one another to create systemic change (Laakso *et al*. 2021, Van Uden *et al*. 2024a).

The MLP is often praised for its explanatory power regarding transitions (Geels 2010), but critiqued for its inability to describe the making or unmaking of rules

that constrain or enable actions or practices (Genus and Coles 2008). Lately, therefore scholars more often apply and promote transition research that also uses one of diverse behavioral sciences (Kaufman *et al*. 2021), of which Social Practice Theory is a dominant one (e.g. Watson 2012, Crivits and Paredis 2013, Cherunya *et al*. 2020, Koretsky and Van Lente 2020). This research incorporates SPT, which can be of additional value, as it focuses on the formation, stabilization, and breaking of practices (Schatzki *et al*. 2001, Schatzki 2002, Shove *et al*. 2012). It can therefore help in establishing how everyday life influences systemic change (Kaufman *et al*. 2021). Use of SPT further allows to better understand change as it is happening (O'neill *et al*. 2019, Van Den Berg *et al*. 2021). Contrastingly, some authors have stated that a synthesis of MLP and SPT results in ontological incompatibility (Geels 2010, Hargreaves *et al*. 2013). However, several studies have shown that given the right definitions, conceptual frameworks can be developed that make use of crossovers (Geels 2010, Van Uden *et al*. 2024b), an interplay of concepts that make use of concepts from both approaches (e.g. Watson 2012, Muylaert and Maréchal 2022).

Before diving into crossovers, this section elaborates on SPT. The focal points of SPT are practices. Every practice encompasses elements, regarding materials, meanings, and skills (Shove *et al*. 2012). Practices enforce themselves (Seyfang and Gilbert-Squires 2019), which helps their reperformance. This is further enforced by the practices on which the practice depends, the system-of-practices in which a practice is performed (Shove *et al*. 2012, Watson 2012). The system-of-practices around these hubs are for instance formed by materials, regarding building components that pass through the hubs from demolition place to new construction sites, the meanings regarding secondary material use that in turn affect other practices, and the skills of overseeing the impact of a design decisions on practices throughout the system.

Every practice, though constantly uniquely performed, knows certain standards, normativized ends and emotions (Schatzki 2002). In the case of CBHs practices, which we consider niche, these are constantly changing (Schot and Geels 2008). Yet, even in niches, changed practices often contain elements of earlier versions of the practice, due to the regime that influences the boundaries in which a niche can develop (Shove *et al*. 2012, Smith and Raven 2012, Laakso *et al*. 2021). Although practices can be replaced by other practices, this would require financial, institutional interventions, via network or regulations and policies (Kivimaa and Kern 2016, Laakso *et al*. 2021). Quite often practices (both niche and regime) are reconfigurations of earlier versions of that practice, containing both old and new elements (Shove *et al*. 2012, Laakso *et al*. 2021). Broken elements can become dormant, re-emerge later, or form parts of other practices (Shove *et al*. 2012). As such, reconfigurations in SPT can be a part of an element, a practice, and the interlinkages of practices, up to the levels of a system-of-practices.

This research does not aim to synthesize the MLP and SPT, but makes use of a crossover, which connects the two approaches in three different ways. First, the MLP is used as a context to help understand how we can interpret systemic change in a system-of-practices. This is a common way to conduct research that does not lead to any ontological connections (Cherunya *et al*. 2020, Heiskanen *et al*. 2024). An important part of this are the notions of niche protection (i.e. shielding, nurturing, and empowerment) that are perceived as parts of practices themselves and form elements to be on the lookout for. As such, they do not interfere with the ontology of SPT. Further, the systemic focus of the MLP is a reminder to not look at one single practice (e.g. repair), but to focus on systems-of-practices. Second, the different levels of the MLP are interpreted as levels of structuration of practices. The logic that practices have different levels of structuration is already common in the work of Warde (2005) and has since been used explicitly in several crossover studies (e.g. Watson 2012, Little *et al*. 2019, Van Uden *et al*. 2024a). To keep the "flat ontology" of SPT (Schatzki *et al*. 2001), the notion that the three levels of the MLP are nested should be let go, as was already suggested by Geels (2010). Third, a combination of practice reconfigurations can become a system reconfiguration, as it is used in the MLP.

With these approaches, we can understand both the change that is happening right now and potential future transitioning. In the methodology section we further elaborate on the operationalization of these approaches.

Methods

This research is centered around the case of the system-of-practices around CBHs in the Netherlands. The Netherlands is often considered a frontrunner for CE in general (e.g. Walker *et al*. 2022) and CBHs specifically (Tsui *et al*. 2023). We defined the scope by taking the hubs as focal point and incorporated practices in the scope of demolition of an old building to design

of a new building. This resulted in the incorporation of practices of building deconstruction, sorting, repairing and refurbishing, procuring, and designing with secondary materials. An emergent theme during early interviews (Creswell 2003) were selling practices, which we then incorporated in the research scope.

This study made use of a variety of qualitative research methods to research this case: interviews, observations, focus groups, and workshops. They were organized in three rounds of interviews and observations and after each round a focus group or workshop was conducted for validation and deepening of the results. An overview of this can be found in Figure 1. The combination of interviews and observation was used to understand practices as they are performed, and have been performed in the past. Observations served as triangulation of the interview results, as is often asked for practice theory research (e.g. Hargreaves 2011), and further enriched the interview results.

As we still know little about CBHs and this study aims to identify relevant themes (Hennink *et al*. 2020), hubs were chosen based on their diversity so that it would become apparent if any of these elements would explain differences in practices or that they would be universal (Mason *et al*. 2010). Differences were sought after regarding size (i.e. among the largest and the smallest firms in the Netherlands), reliance on material gathering (components gathered by themselves or by other companies), and locations in the Netherlands. An overview can be found in Table 1. Further, to understand CBHs in the CE transition in the case of the Netherlands, all hubs had to be based in the Netherlands, deliver business-to-business, be active already so practices can be observed, be big enough to supply to construction projects, and provide building components, not just raw materials.

In total 8 hubs were found that fulfilled all criteria, and 14 interviews with hub employees have been conducted, with four additional observations at hub locations and a fifth at a deconstruction site. Observations regarded the activities that were taking place, such as deconstruction, sorting, repair, cleaning, and work in the sawing mill at the hub. During observations, questions have been asked to understand why practices were being performed the way they are. Special attention was paid to the materials related to the practices, as these often enforce practice reperformance (Shove *et al*. 2012). Through snowballing, other practices and their performances were found, resulting in 7 interviews with architects with experience in construction projects with reuse ambitions, 2

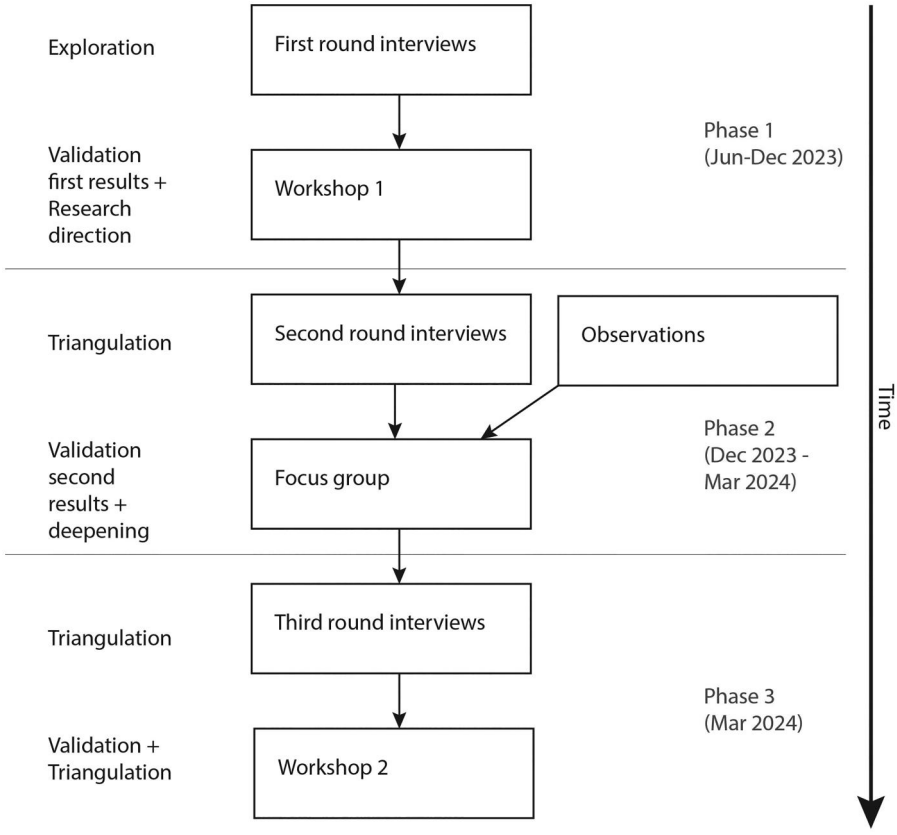

Figure 1. Overview research methods.

Table 1. Overview of CBHs.

Hub	Size (employees)	Part of existing organization	Family company	B2B or B2C
1	85 + 65 Flexible	Yes, demolition/deconstruction	Yes	B2B
2	70	Yes, demolition/deconstruction	Yes	B2B and B2C
3	5 + 3 Flexible	Yes, diverse	Yes	B2B and B2C
4	200 + 220 Flexible	Yes, demolition/deconstruction	No	B2B
5	5	Yes, contractor	Yes	B2B
6	5 + 5 Flexible	Yes, diverse	Yes	B2B and B2C
7	3 + 3 Flexible	No	No	B2B and B2C
8	250	Yes, demolition/deconstruction	Yes	B2B

Table 2. Overview of interviewees.

No.	Interviewee	Length	Hub (Table 1)
1	Hub employee	0:52 hour	4
2	Hub employee	1:22 hour	4
3	Hub employee	1:38 hour	3
4	Hub employee	1:04 hour	3
5	Hub employee	0:23 hour	1
6	Hub employee	1:41 hour	2
7	Hub employee	0:44 hour	4
8	Hub employee	0:45 hour	4
9	Hub employee	0:29 hour	6
10	Hub employee	0:41 hour	7
11	Hub employee	0:28 hour	6
12	Hub employee	0:48 hour	5
13	Hub employee	0:53 hour	8
14	Hub employee	0:52 hour	4
15	Architect	0:48 hour	
16	Architect	0:37 hour	
17	Architect	0:31 hour	
18	Architect	0:38 hour	
19	Architect	0:22 hour	
20	Architect	0:57 hour	
21	Architect	1:15 hour	
22	Online sales platform employee	0:54 hour	
23	Online sales platform employee	1:00 hour	
24	Non-academic expert	0:53 hour	
25	Non-academic expert	0:37 hour	
26	Supplier	0:55 hour	

interviews with an online sales platform, 2 interviews with non-academic researchers on circular construction hubs, and 1 supplier that took back materials from hub companies. On an average, interviews lasted about an hour, ranging from 22 minutes, to 1:41 hours. Questions focused on barriers and enablers, determining practices (including practice elements, i.e. meanings, materials, and skills), including past reconfigurations and expected future reconfigurations. During analysis, names of interviewees and companies have been anonymized. An overview of these 26 interviews can be found in Table 2.

As further validation of interview and observation results after phase 2, a focus group with hub employees and non-academic hub experts was organized with a focus on barriers and enablers in the current system, and perspectives for future practice reconfigurations.

Lastly, 2 workshops were organized. The first had 19 participants, consisting of hub employees, architects, public clients, contractors, branch organizations, and academic researchers. It focused on the changing role of demolition companies, and the changes made and needed by other actors. Participants were divided in small groups and asked to think from a different role and describe challenges. Eventually, plenary reflections took place. A report was drafted afterwards which included the most important findings. The second workshop had 29 participants, consisting of hub employees, employees of an online selling platform for secondary materials, public clients, contractors, consultants, and academic researchers. The aim was to understand the current system of reverse supply chains, the envisioned future, and the options and barriers to get there. In small groups participants worked on the system for different specific building components, and reflected on comparisons and differences in a plenary session. Afterwards a report was drafted with the most important notions.

Interviews and focus group discussions were transcribed *ad verbatim* and along with the workshop reports coded in three rounds using Atlas.ti. The first round of coding was deductive, focusing on both past and future reconfigurations of practice elements (i.e. meanings, materials, and skills), enablers, barriers, and transition directions regarding the full system-of-practices. This followed quite directly from interview questions, as they specifically focused on these elements: interviewees often elaborated on the elements that remained the same and the elements that had changed. Then, with these elements, it became important to sort them in different practices. For this, several categorizations were developed, based on emerging themes. Three alternatives were discussed among the authors that grouped the elements differently. The final division in practices was determined on the presence of an inner logic per practice and a total amount of practices that would not be so large that it would obscure overview. We found that this also often, but not always, coincided with personnel, for instance repair personnel often would not sell, and deconstruction personnel often would not repair, though usually CBH employees had had experience in both at certain points in time. This led to the following emerged practice groups: (1) deconstruction, (2)

Table 3. Regime and niche dimensions, based on Smith (2007) and Van Uden *et al*. (2024a).

	Regime	Niche
Principles	Mainstream guiding principles (e.g. profit and loss)	Alternative guiding principles (e.g. minimize ecological footprint, closing loops)
Technologies	Tried and tested technologies and infrastructure (e.g. design with concrete structure)	New technologies and infrastructure (e.g. design with reused concrete)
Industrial structure	Industrial structure *en masse* (e.g. subcontracted labor, volume building)	Alternative industrial structure (e.g. use of secondary building components)
User relations	Traditional user relations and markets (e.g. passive and conservative consumers)	Active user relations and markets (e.g. actively steering clients)
Policy	Following policy and regulations (e.g. MPG[a] minimum is standard)	Challenging policy and regulations (e.g. lowering MPG goals for a project)
Knowledge	Knowledge based on existing competencies and business practice (e.g. standardized designs/ solutions)	Knowledge base for alternative guiding principles (e.g. knowledge of low-impact materials)
Cultural, symbolic meanings	Broadly shared cultural, symbolic meanings (e.g. markets and regulations)	Alternative cultural, symbolic meanings (e.g. circular housing)

[a]MPG is Milieu Prestatie Gebouwen, the Dutch standard on shadow costs, which are based on Life Cycle Analyses. The current standard is achievable without extensive measures.

storage, repair, and refurbishment, (3) selling, (4) design, (5) procurement, and (6) supply. Among the authors, we discussed in several stages which practices were needed to come to a full system-of-practices for these hubs. We decided on these six, as eliminating some from the results would raise questions, and adding more would add confusion. When these six practice groups were determined, this led to extra interviews in phase 3 (Figure 1). In round 2, practices were inductively coded, categorizing groups of similar reconfigurations per practice group. Results were discussed in consecutive workshops and focus groups, and eventually among the team of researchers to determine the most important results. For past reconfigurations, we divided the results into (1) the reconfigurations themselves that show changes in meanings, materials, and skills, and the enablers that made these reconfigurations possible, and (2) the challenges that hinder further reconfigurations. Further, we divided future reconfigurations into short-term and long-term reconfigurations. All of this relates to the explorative forecasting of practices by practitioners themselves. This has three major limitations: (1) the forecast may be precise and at the same time inaccurate, (2) they cannot be trusted as behaviors that stimulate trends might change, and (3) they are incomplete (Puglisi 2001). Despite these important limitations, they are an important part of futures studies. During interviews, the interviewers remained critical if the predicted future was too much in the advantage of the person interviewed. But, surprisingly, we found that many practitioners, especially hub employees, were somewhat negative about the prospects of their practice. This, to us, enhanced the trustworthiness of the statements (i.e. that their forecasts were actually what they were thinking was going to happen instead of what they were hoping was going to happen). Further, important to note, these forecasting results should not necessarily be interpreted as a likely future, but more as a better understanding of the practices in the present and the reconfigurations that are happening now. All of this is incorporated in the section below. Note that the results therefore relate to reconfigurations in practices, and do not describe practices themselves. After distinguishing practices and their (potential) reconfigurations, practices were coded on being niche or regime, using the dimensions of Smith (2007), that were translated by Van Uden *et al*. (2024a), and can be found in Table 3. Lastly, it was coded which notions of niche protection (shielding, nurturing, and empowerment) were present in both past and notions of potential future reconfigurations. This niche protection can help indicate which parts of the future are thought about, and which are not, which influences the likeliness of those futures. These are discussed in the discussion.

Results

As shown in Figure 2, components travel through the system-of-practices in several ways. From deconstruction sites, they are collected by CBH employees. Sometimes they are stored and/or repaired or refurbished in the hub, but in most cases components are first sold and later directly transported to (1) virgin component suppliers, (2) middlemen that specialize in specific components, or (3) new construction sites, where they become part of design and/or procurement practices. Components therefore do not always become part of every practice in the system-of-practices. Also, sometimes practices sometimes start working with components without them changing location. For instance, with reuse, it is a common strategy for a new design, to visit buildings that are prepared for

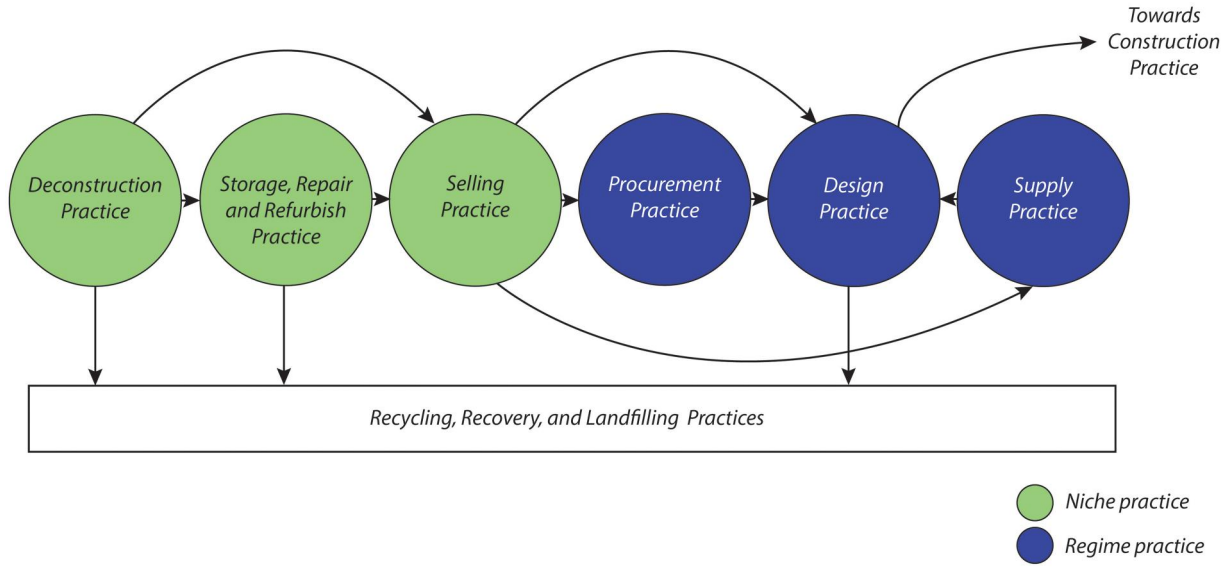

Figure 2. Flow of building components in system-of-practices in which CBHs reside.

deconstruction. Deconstruction and selling teams will then help architects make choices on the use of specific building components. Yet, as a result, the design will have been made, while the components are still in an old building. As such, components can become part of several practices at the same time while remaining in the same place. Figure 2 should therefore not be confused with a linear supply chain, as it helps in giving an overview of which practice(s) work(s) with a component, and not of the location of that component.

After design, components can become part of construction practices, which have been outside the scope of this research. When something goes wrong (e.g. a component gets damaged) it can become part of recycling, recovery, or landfilling practices, which are also outside the scope of this research. Though strictly speaking, CBHs only have to be part of the storage, repair, and refurbish practice, that practice highly influences deconstruction and selling practices, which are usually also performed by employees of that same company. Further, indirectly the other practices of the system-of-practices are also influenced by the CBH.

The result section is divided into two parts. First, we will discuss past practice reconfigurations of the system in which circular hubs reside. This includes challenges for reconfiguration. Second, we will discuss potential future reconfigurations practitioners deem likely for their practices.

Past reconfigurations

Reconfigurations of practices have taken place throughout the system. This section takes a look at (1) deconstruction, (2) storage, repair and refurbishment, (3) selling, (4) design, (5) procurement, and (6) supply practices and describes the formation, drivers, and challenges of current practices. Deconstruction and storage, repair and refurbishment have undergone major reconfigurations. Selling secondary components is a new practice and poses many challenges. Consequently, design, procurement, and supply practices have undergone only minor reconfigurations so far. This will be discussed in more detail per practice below.

Deconstruction practice

Reconfigurations. Deconstruction, as reconfiguration of demolition, requires new meanings (e.g. mindset), new materials (e.g. tools), and new skills. New meanings for instance regards patience, as deconstruction takes longer, around 30% one interviewee said. One hub employee (#7) said: "if you lack patience, you just start ramming it until it breaks". The change of tools can relate to the deconstruction itself, such as use of precision or manual tools compared to for instance a hammer, but also to new storing containers (e.g. crates, carts, sea containers), or even tower cranes. Before deconstruction teams start, material specialists inspect the building using digital tools, to determine a price, what is to be deconstructed, to allow the start of the selling process, and to make material passports. New deconstruction skills for example regard knowledge of old construction standards.

Challenges for further reconfigurations. Driven by the global climate crisis, a growing number of deconstruction tenders asks for specific minimal reuse

amounts and stimulates to top that. However, often not enough time is given for deconstruction, as demolition is faster and clients often lack knowledge about this. This often results in a mixture of deconstruction and demolition. Tenders also often demand demolition, as it is cheaper, so the practices exist next to one another, performed by different teams. One hub employee (#3) said "demolition people were always rough [.] and now we have a role next to that, but we can still be rough if we want to". Reconfiguration from demolition into deconstruction proves difficult, as demolition has the attraction of "breaking something hard" (#1). Lastly, existing buildings contain diverse components and connection methods, making it difficult to learn all existing elements. Further, deconstruction is a skill you can get better at, but early disappointing results hinder progress, as demolition workers fail to see the point of deconstruction. Many companies see potential in employing people with a distance to the labor market, so as to make a social impact, and be able to work cheaper, as this is subsidized. As they are new employees they do not need to unlearn demolition practices, but instead specialize in deconstruction.

Storage, repair, and refurbishment practice

Reconfigurations. After deconstruction, 30% of the components are stored at the hub, but most move to a new client, middlemen, or supplier. Hubs are not new, but a variation on old hubs. Many demolition companies used to have one, but it was (1) a shady business, and (2) not financially capable to challenge the cheap hardware stores that popped up since the early "70s, so many disappeared". To make them valuable again, new meanings had to be connected to the hubs (e.g. making them symbols for a circular economy). Now the number of hubs is growing and they are legal and professionalizing. This practice can therefore be considered a reconfiguration of a "sleeping" practice.

CBHs are used for storage, which is lengthy compared to logistical hubs, but also for repair and refurbishment, which also happens at social working places, or via middlemen. This concerns a wide variety of materials. This is for instance popular for wooden beams (many hubs have installed saw mills), or even tropical hardwood, which is often used in window frames. An advantage is that many components are (re)standardized. Other often processed components include steel structures, planks, insulation panels, ceiling tiles, doors, kitchens, dividing walls, toilets, and glass. Many other components are either recycled (e.g. concrete crushed for road filling or new concrete) or landfilled.

Skill development was essential in making CBHs function as reasonable alternative for virgin supply chains. It required financial investment and continuous learning, to make a valuable business model for repair and refurbishment (e.g. product development, determining quality, or knowing when to remove nails or cut a beam), so to be able to mass-produce. Further, as employees who deconstruct also had experience in repairing and refurbishing, they created feedback loops.

Challenges for further reconfigurations. Contrastingly, components received from other deconstruction components are often of bad quality and cannot be properly repaired or refurbished. One hub employee (#7) said: "sometimes we try taking components from others, but then you see the quality is lower and you have to either fight over it or check every component individually. We cannot do that." This limits growth capacity of CBHs.

Selling practice

Practice development. Selling components became a new practice with the rise of CBHs, often met with unease. This shows the need for further meaning development, for instance in the reluctance to price components. However, it also allowed for new jobs for commercial employees, whose sole purpose is to sell components. Many hubs have lists with standard buyers (business-to-business (B2B)), but this needs constant updating, as different materials start selling. This, in turn, also affects the deconstruction practice. One hub employee (#2) said: "we are testing all the time", which also shows continuous knowledge development.

Materials for the selling practice relate to building components, selling media, like online marketplaces, but also sometimes to the hubs themselves. Business-to-consumer (B2C) often happens at the hub, but as this is time intensive and does not allow for selling large quantities that come available simultaneously, many CBHs prefer focusing on or shifting to B2B. One hub employee (#1) explained this: "for us it's often everything or nothing. If we have a project and we know what comes available, we want a client at that point in time for that amount of material and not a part or a week later". For B2B, selling often goes through external digital marketplaces, such as Marktplaats[1] or non-profit foundation Insert[2], or their own website. Interviewees mention demand is slowly

growing, mostly to architects or contractors, wholesale, suppliers, and middlemen that clean, repair, refurbish, and label specific components. Both selling and the design process require time, so CBHs aim to start selling when the components are still in the original building.

Challenges for further practice development. Several challenges hinder further market growth. Selling beforehand does not always work out, as both supply and demand are irregular. Supply is also bigger than demand, so many components stay on the hub and are eventually recycled or landfilled. Further, reuse, especially when repair or refurbishment is needed, is labor intensive and therefore expensive. Hubs cannot demand large enough margins to make a great profit. Lastly, load bearing components often sell badly, because guarantees are difficult to give, although this challenge is slowly being overcome. Recently process norms have been developed for steel, and work started for concrete. Also for other components sometimes quality marks are needed to sell them (e.g. FSC for wood). Sometimes quality marks can be added by the supplier.

Design practice

Reconfigurations. Design practices so far seem to largely remain the same regarding reuse. The "stickiness" of the practice shows that the practice is a regime practice, at least regarding reuse. Some practice performances might be considered niche, but seem to remain exceptions. Nevertheless, though not large-scale, reconfiguration for reuse have been highlighted in several practice performances. First, as design practices need reconfigurations regarding skills so as to understand how building components can be reused, deconstruction companies increasingly inform the design process with knowledge on deconstruction. However, they are often not accustomed to that role and need to learn the language of the design process. At the same time, sometimes deconstruction companies even become contractors to overcome reuse barriers. Second, two streams for design with reuse have been developed, with each their own reconfigurations regarding meanings, materials, and skills: (1) design-for-disassembly and (2) direct reuse. Some architects have become very active and skilled in searching for secondary components themselves, which also costs time and money. Yet, most reconfigurations seem to relate to the first streams. They are specializing in the ultimate details for deconstruction, influencing future deconstruction practices.

Challenges for further reconfigurations. Several challenges hinder further reconfigurations. First, regarding the second stream, increasingly, architects hand wish lists to CBHs. Yet, many architects still struggle with irregular supplies of components that require flexible designs. Often this results in falling back to traditional design practices. One architect (#16) elaborated: "along the way, sometimes you know you fall back on traditional ideas or thoughts because of risk or cost or whatever. And then you think we weren't as far as we thought we were". Further, when searching for components, architects need a lot of information, most of which is often not available on websites, and often they want to see and feel components. Also, quite often reuse is not implemented as it is deemed too expensive. Lastly, reused components can result in new aesthetics, which architects and clients often dislike.

Procurement practice

Reconfigurations. Similar to the design practice, procurement practice also seems difficult to change, showing that this is also a regime practice, at least regarding reuse. Interviewees mention therefore only several small reconfigurations for the procurement practice. First, increasingly public clients tender with criteria regarding deconstruction or reuse for new construction. Tenders sometimes demand a specific percentage to be reused and give discounts if deconstruction companies manage more. This requires a reconfiguration in skills, where clients need to know what they can tender. For this, increasingly clients collaborate with consultancy firms. And what is deemed tenderable is based on what consultancy firms deem likely. More often, tenders now include effort obligation regarding reuse, as knowledge about what can be reused is not developed enough yet.

Challenges for further reconfigurations. Several challenges hinder further reconfigurations. First, clients often still lack knowledge about (1) what can be deconstructed, and (2) how much time this costs. Further, as the market changes quickly, the information that clients gather is often outdated after a short while. Lastly, as tenders often include best effort obligations, and seldom strict demands, initiative often has to be taken through other practices. One architect (#13) elaborated: "I think in many cases we still need to propose it, because either clients haven't really thought about it or they did think about it, but thought it would be too expensive or that they simply just don't know".

Supply practice

Reconfigurations. Supply practices. As regime practices have also shown very little reconfigurations, because so far few suppliers take back building components, and the ones that do often make only very few changes in their practices. Nevertheless, in recent years CBHs have developed partnerships with several suppliers for simpler materials such as products as wooden beams, floors, and plasterboards. In these cases the components had diverse origins, and were often originally manufactured by different companies. For these products, the quality has remained similar in the last decades. For instance, secondary plasterboard is now often reused as first layer for new walls, as it still suffices regarding fire safety and acoustics. Without reconfiguration of skills, suppliers can therefore easily add quality marks to these products. However, as the product was not designed for disassembly, the secondary component is cut during deconstruction, and therefore smaller. In the case of wood, CBHs often remake wooden beams into new standards that suppliers then sell, or in the case of window frames, specialist companies use finger joints to make these into modern standards. This is especially interesting for tropical hardwood, as its quality is now difficult to match with virgin wood.

Challenges for further reconfigurations. Returning components to suppliers has often proved difficult due to legal and financial reasons, and results in collaboration for recycling instead of reuse. Also, so far, the interest for secondary components is inconsistent, and in general relatively low. Therefore, clients for secondary components are actively sought after by suppliers. One plasterboard supplier (#26) said: "We are contacting all hospitals in the Netherlands [...] to tell them this story".

Future reconfigurations

In general, practitioners see several large elements impact their practices in the future regarding policy, market, and technology. First, policies (e.g. the MPG[3] or EU CO2 legislation) will stimulate procurement for reuse and allow business model development for this. This will be further secured by norm development and public procurement for (de)construction. This will stimulate (1) design-for-disassembly and standardization, (2) direct reuse, (3) development of circular components, and (4) renovation at the cost of new building. Second, the market plays a pivotal role. There are several market drivers. First, rising prices of virgin materials are expected to stimulate reuse. Second, actors are professionalizing and increasing awareness, which is expected to continue. Third, large and family companies are expected to take a lead as they can afford to make investments. It is expected that this will lead to architects using CBHs more, and hubs to specialize and increase in size and quantity and get more ideal locations. However, long term, hubs are expected to decrease in size and quantity, and become more focused on logistics and move components to either suppliers, or middlemen, specialized in specific components. Third, technology plays an important role. Practitioners see much potential in a digital built environment, as it can provide an overview of components that become available. It is expected that policy is influenced by this information.

The rest of this section further discusses future practice reconfigurations per practice and the (un)certainty of these based on existing trends. During analysis, we noticed that short-term and long-term change sometimes regarded different transition directions, so we distinguished between them. Short-term change regarded changes foreseen in the next one or two years, and long-term changes regarded changes up to 2050, in line with the Dutch/EU policy agenda. It is noteworthy, that although practitioners see trends happening, for some major ones, it remains unclear for them how these affect their practices directly (e.g. how a digital built environment should be implemented in deconstruction and procurement practices). Lastly, many of these reconfigurations play a role on a large scale, in the system-of-practices, whereas it changes little for individual practices.

Deconstruction practice

Practitioners expect various reconfigurations of deconstruction practices. In comparison to many other practices, a lot and continuous change is expected. In short term, practitioners expect knowledge development regarding deconstruction processes, and technical qualities (e.g. insulation values). The practice is also expected to grow, especially with low-hanging fruit. This would be a continuation of existing trends. Further, as competing demolition companies will become better at deconstruction, they might also provide components to CBHs or suppliers. At the moment, this makes sense for components of which there is always shortage (e.g. wood and plasterboard), but for other components this might also require increased demand.

Long-term reconfigurations are expected to contain more assignments for circular deconstruction, due to

increased awareness, procurement skill development, and laws and regulations that stimulate reuse. Realization of this largely depends on political developments that remain highly uncertain. Further, deconstruction is expected to go faster, as more buildings are being designed for disassembly. This makes sense if the trend for design for disassembly continues and grows, which also remains uncertain due to the sepsis involved. Lastly, digitalization and optimization are expected to play an important role. Deconstruction projects will be bundled, made digitally available, and planned as a singular, more efficient assignment. One interviewee (#25) elaborated: "If you want to make the logistics processes cost efficient, you need a bigger scale for your circular processes. So you have a big scale to do urban mining, which means you have fully loaded transport trips with materials and store them and reuse them again". Eventually the practice is expected to grow significantly: within large companies, circular parts will merge with traditional parts, and smaller companies will follow the frontrunners. Noteworthy, although a lot of faith is put in this digital built environment, practitioners offer few details of how this will affect their practice. This development therefore still holds many questions.

Storage, repair, and refurbishment practice

Practitioners expect various reconfiguration regarding storage, repair, and refurbishment practices. In short term, they expect to experiment with materials they have not experimented with before (e.g. new wood products). Further, they expect an increase in CBHs and size of them.

Long term, reconfigurations are expected in opposite direction: CBHs are expected to shrink spatially, and contain less components, because these go directly to suppliers. CBH companies will become more logistical networks than storage, repair, and refurbishment spaces. One hub employee (#14) elaborated: "Later I see us as an important logistics company: we deconstruct elevators and bring them to the supplier, we bring toilets to the client, wood there. For the future I do not see why we would still need a saw mill". As a whole, the market is expected to grow. For this, more ideal locations (e.g. connected to water) are necessary to better bundle components and a control system to manage resource flows. Many hubs might have temporary locations, and be specialized in specific building components, or building phases, as combining different types of components becomes inefficient when used large scale. Whether these reconfigurations take on largely depends on supply practices, and the likeliness of suppliers to take on more products, which so far has proven difficult due to laws and regulations, and business models.

Selling practice

Short term, various reconfigurations are expected: what sells probably keeps changing, and knowledge about that and about the price needs to be constantly updated. Also, more awareness about (the need for) guarantees is expected, especially when public clients (e.g. municipalities) are reusing their own components. Further, Insert might incorporate CBH locations, CO2-impact, more pictures of components, and more available components and details in general. Lastly, sales employees might improve their knowledge on the type of information that different actors need. All of these reconfigurations are likely, as they follow previous reconfiguration trends.

Here, again, long-term reconfigurations are expected in different directions: the online selling platform is expected to first get better accepted and then disappear. One employee (#23) elaborated: "In my opinion we will not have a digital marketspace in ten years' time. The system will then have changed so much that it will regulate itself without a marketplace [...] There will be flows in connecting people and materials. You will have companies who have circular doors, who will have circular sanitary, who will have circular windows. So you will have specialists. [...] And secondly, if we digitalize, let's say our cities or our villages, our buildings, public areas, then we will know when materials come out of a building, when they are end-of-life, and what we need to do". The market for secondary products is expected to grow, especially business-to-business. Eventually, hubs are expected to deliver mostly to suppliers or middlemen that specialize in specific components, and remain to deliver only to the finishing phase of construction projects. Again, the likeliness of these largely depends on (1) overcoming challenges regarding business models, and laws and regulations for suppliers to take on secondary components, and (2) the implementation of a digital built environment, for which there does not seem to be a clear idea for implementation in practices.

Design practice

Various reconfigurations are expected in design practices. Short term, more courage is expected from architects and contractors to start designing with reused materials. This also entails becoming more flexible with the use of specific components. Further, more

and earlier involvement of deconstruction companies or other specialists is expected to better understand what design-for-disassembly means ideally. Though this last point seems to be happening already, the likeliness of the rest is debatable, as design with secondary resources is so uncommon, that it is difficult to distinguish trends from existing projects.

Long term, the system is expected to have undergone more fundamental changes. First, better design-for-disassembly will result in standards, and new, wider accepted aesthetics. Second, much of the current system is expected to be part of a digital built environment, allowing knowledge on when components become available. This asks for a new process in which architects are assigned a list of materials – instead of *vice versa* – with which they design a building for longer periods of time. Eventually, architects will take a long responsibility for temporary actions (i.e. the lifespan of a building), making the job more about logistics, and less about construction, similar to the car industry. Although some architects seem to be working in this direction, for a change of the design practice overall much depends on the uncertain implementation of a digital built environment.

Procurement practice

Procurement practices are expected to have various reconfigurations short term. First, they are expected to professionalize regarding realistic budgets and planning, allow visits to the site on time, expect component storage on site, know what can be reused, and better knowledge on how to set up tenders for reuse. This would mean a continuation of current reconfigurations. Also, an increase in tenders for reuse is expected. This still seems to be a larger step that seems most likely when "donor" buildings are part of the same project as buildings that would demand these components.

Long term, other reconfigurations are expected. First, rising material costs are expected to lead to more procurement for reuse. Second, laws and regulations on CO_2 or reuse specifically are expected to stimulate procurement for reuse. In the Netherlands, the first would probably entail better testing and sharper demands of the MPG, or (CO_2) taxes. Tenders are expected to shift towards maintenance and renovation, and design-for-disassembly. This is largely due to building law preventing reuse of many components in new buildings. Also here, the likeliness of these reconfigurations depend on uncertain political developments.

Supply practice

Short term, some regulation updates are expected that allow suppliers to give guarantees based on a process. Some of these are new (e.g. steel), and some are in the making. This therefore seems likely.

Long term, more reconfigurations are expected. First, stimulated by laws and regulations many expect that suppliers will take back more components for repair and refurbishment. This would require new business models, as current business models often do not stimulate this. Suppliers would then maybe become the new owners of these components and provide them as a service. So far, this development is highly uncertain.

Discussion

These results offer interesting points for ongoing academic debates, for which we want to highlight four: (1) the relation of CBHs with logistical hubs, to better understand what a CBH is, (2) CBHs and the practices of reuse, to better understand the effect of CBHs on reuse, and (3) the specific niche protection that allow for development of this niche. Niche protection has proven vital for innovations to be able to compete against regimes and this gives us a better understanding of how CBHs could have emerged (Smith and Raven 2012). (4) This discussion also highlights why we think that the rise of CBHs is also only limited, as incumbent regime practices remain largely untouched by niche protection.

CBHs might easily be confused with logistical hubs, but this analysis shows that on a practice level there are actually great differences between the two. First, they have very different origins that influence current practices: logistical hubs are usually installed to improve construction processes, whereas CBHs have their foundation in deconstruction and associated practices. Both types of hubs handle building components, but whereas logistical hubs often have clear plans with these, CBHs often do not know when and to whom they sell these components. Consequently, components remain on the hub much longer. Further, what is done with these materials is very different. Whereas logistical hubs are mainly used to overcome logistical challenges, in CBHs components are repaired, refurbished, and actively sold, making CBHs more complex and fundamentally different. However, many interviewees mentioned a future for CBHs with less focus on these extra practices and a larger focus on the logistical processes, meaning that even though these hubs have different origins and are loci for

different practices, both hubs might become more similar and co-develop. CBHs can also be confused with material hubs, that mainly recycle, which has proven easier to scale up. This research shows that these processes often go hand in hand, as components that cannot be reused, often can be recycled, and the combination of these help overcome financial strain on CBHs. If CBHs grow, their dependence on recycling might become less. This relates both to reuse being more of an option, and recycling having to serve less as a successful business model while CBHs are being developed. With this distinction, this research contributes to the gap of knowledge on CBHs in supply chain management literature.

Of all circular design strategies, design with secondary resources, and especially direct use of secondary building components, seems especially difficult (Van Uden *et al*. 2024a). Literature has described many barriers for reuse, such as small or absent markets (Munaro *et al*. 2020), low quality of components (Adams *et al*. 2017, Ababio and Lu 2023), missing data of existing buildings (Koutamanis *et al*. 2018, Van Den Berg *et al*. 2021), difficulty with guarantees (Kooter *et al*. 2021), a missing logistical structure for secondary components (Nußholz *et al*. 2019), hesitant procurement behavior (Adams *et al*. 2017), and lacking design skills (Gerding *et al*. 2021, Van Den Berg *et al*. 2024). This research confirms several of these barriers, but also shows that CBHs can be used to overcome some of these. First, interviewees mentioned the low quality of components if hubs received these from other demolition companies, but as CBH employees were involved in both deconstruction and repair, they noticed a feedback loop that improved component quality after deconstruction. These hubs, especially when connected to a well-established online selling platform such as Insert, or suppliers that can guarantee the quality of components, form a small logistical structure that allows for a growing market of secondary components. Second, this study confirmed that missing data is a large barrier for reuse. We found that practitioners see potential in a digital built environment to help overcome this barrier. However, earlier research highlighted the difficulties in implementation of digital models in routinized practices (Van Den Berg *et al*. 2021) and this research shows that so far practitioners do not have a clear vision of how a digital built environment would impact their practices. Third, this research confirms that there is still hesitant behavior regarding procurement for reuse, even though interest is growing. This lack of procurement combined with lacking product information on online marketplaces, hinders architects in developing new design skills for reuse, which is still happening, but slowly. Similarly, this research also confirms hesitant procurement for circular deconstruction, which we found, in line with earlier research, also relates to lacking knowledge and awareness (Van Den Berg *et al*. 2023). Concludingly, CBHs have formed an important factor in overcoming barriers, but this is not enough to overcome all of these and create a fully developed alternative supply chain to virgin components. Especially the second half of the supply chain, relating to design, procurement, and supply needs development to overcome further barriers. This is unsurprising, as regarding reuse, these have proven regime practices. This is an important message for policymakers and managers in these supply chains, as it shows that the positive elements of CBHs do not immediately translate to reuse itself, as other practices should also be considered. With this overview of how CBHs help overcome barriers for reuse, this research contributes to prevailing insights on reuse and a circular economy in construction management literature.

Lastly, this discussion delves deeper into the protection that allows CBHs to develop as a market and logistical niche. Protection can include shielding, nurturing, and empowerment (making niches competitive), all of which can influence each other (Smith and Raven 2012). First of all, most obviously, many CBHs are shielded as they are part of larger, often also family owned, companies. This allowed for development of skills, meanings, and materials, without immediately having to make a profit, as the rest of the company could compensate for that. This helps overcome the barrier of large investments for these specific companies (Ababio and Lu 2023). In many cases, both deconstruction and storage, repair, and refurbishment practices, are therefore shielded demolition practices, and sometimes by other, such as recycling practices. CBHs are further shielded, as they often make use of existing (logistical or material) hubs, which allows smooth growth and shrinkage without large investments. This directly influences deconstruction, storage, repair, and refurbishment, and selling practices, and indirectly the other practices in the system-of-practices. Second, CBHs are nurtured as they make use of subsidized employees with a distance to the labor market. This provides a learning space, but as these people do not need to unlearn practices, it often also saves time and delivers quick wins. Apart from this business perspective, it also creates social impact. This strategy is functional for the current scale of CBHs, but it can only be scaled-up to a certain extent. The

impact is mostly on deconstruction, and storage, repair, and refurbishment practices, and influences other practices barely. CBHs are further nurtured on an institutional level with the development of guarantee norms for secondary components based on processes. This currently exists for steel and the norms for other materials are under development. This development highly influences practices throughout the system-of-practices. Third, CBHs are empowered by delivering components to suppliers and therefore aligning with current industrial standards regarding actors, locations, and even quality marks. This minimizes (the need for) practice reconfiguration for architects and contractors and therefore changes storage, repair, and refurbishment, and selling practices, while confirming current design and supply practices. Interviewees complained that typical empowerment through new regulations (Smith and Raven 2012) is still lacking, but did notice that existing policy goals for a circular economy were enough to already boost interest in secondary components, mostly among private actors. Similarly, in line with earlier research (e.g. Adams *et al*. 2017), public procurement for reuse is also still largely absent, as public actors are hesitant to demand use of the small secondary component market. This, in turn, hinders its growth. Concludingly, shielding and nurturing does take place, which has helped initiating this niche development as part of larger companies, but empowerment is still largely absent, even though some traces of it are present. When examining future practices, many interviewees also focus on empowerment in the form of changing laws and regulations, increased procurement, and increased use of existing suppliers that also take over repair and refurbishment. All of this would make the niche less radical and more similar to regime practices of virgin components. Which niche protection is needed for implementing a digital built environment was not brought up by interviewees, showing much uncertainty in this regard.

All in all, shielding, nurturing, and empowering seem to have most influenced deconstruction, storage, repair, and refurbishment, and selling practices, while design, procurement, and supply practices remain largely untouched. As these are, at least regarding reuse, regime practices, this is unsurprising. To further overcome barriers for reuse, it might be necessary to stimulate niche formation for these practices and protect these accordingly. Protection of the new or renewed practices is not enough to force a transition, as changing incumbent practices is needed as well. Whereas some of these practices are helped with niche protection (e.g. design practices change, as training with MPG calculations is subsidized), this still does not affect reuse directly. It is noteworthy that in the forecasts of practitioners, these regime practices will change, stimulated by professionalization of the hubs, and not through niche formation and protection, as would seem likely from this research.

Lastly, this research shows that using concepts of the MLP in a SPT context helps to explain why change is happening, and hints how change in practices can be further stimulated. Perceiving CBHs as a system-of-practices with practices that are either niche or regime, allows to both show which change is happening (i.e. in which practice elements) and in what manner (i.e. slowly and barely (regime), or in general and continuous(niche)). This is especially useful in parts of the system where both niche and regime practices are present, as is the case here. This lens gives transition researchers extra tools to study transitions on both a systemic and a small scale, as is often asked for by scholars (Geels 2010, Kaufman *et al*. 2021, Van Uden *et al*. 2024a). So far, this lens is mostly applied for a single practice, or opposing practices (Crivits and Paredis 2013), but according to a recent systematic literature review (Van Uden *et al*. 2024b), this research is one of the few that uses a crossover between MLP and SPT on a scale where several practices are involved in a system-of-practices. This allows for novel analyses on interactions between niche-practices and regime-practices, and thereby contributes to transition literature that aims to incorporate behavior (Kaufman *et al*. 2021).

Conclusion

By conducting interviews, observations, workshops, and a focus group, this research aimed to answer the following research question:

Which reconfigurations have taken place in the system-of-practices in which circular building hubs reside regarding reuse of secondary building components and how is it deemed likely to transition in the future?

We answered this question by analyzing recent reconfigurations in practices and future reconfigurations deemed likely by practitioners in deconstruction, storage, repair and refurbishment, selling, design, procurement, and supply practices. We found that reconfigurations mainly took place in niche practices: deconstruction, storage, repair, and refurbishment, and selling practices. Reconfigurations were stimulated by private companies who used shielding and nurturing, e.g. by giving time to develop a working business

model without having to make a profit, or through use of subsidized labor forces. These niche practices reconfigured from demolition practices, changing rapidly and continuously, using "sleeping" elements such as "shady" hubs that reconfigured into CBHs. Examples of new elements in existing practices include using saw mills, making new components (e.g. diverse wooden beams) from old components, selling products through online platforms, and patiently deconstructing elements from old buildings. This resulted in overcoming some barriers for reuse mentioned in earlier literature, such as low quality of components, lacking guarantees, and a missing logistical structure. However, some barriers are still present, as fewer reconfigurations take place in design, procurement, and supply practices. Consequently, hesitant procurement behavior and lacking design skills still form an important barrier for further reconfigurations. Nevertheless, also in these regime practices (at least regarding reuse), reconfigurations take place. For instance, some suppliers take simple products back that they sell themselves.

For the future of the system-of-practices in which CBHs reside, we distinguished between short-term and long-term change. Short term, professionalization in practices is expected. This regards, for instance, better allocated time for deconstruction, selling components with more details (e.g. price, measurements, location, and environmental savings), and skill development for architectural design with reuse, influenced by deconstruction companies. All of this follows current reconfiguration trends. On the scale of the system-of-practices, hubs are expected to grow in size and number. This seems most likely if procurement for reuse grows, which requires more than merely professionalization of practices. Long term, the expected transition direction is very different, a digital built environment will is expected to inform future procurement and design so that many hubs will shrink or seize to exist. However, there is still little understanding of how a digital built environment should be implemented in practices of construction professionals. Consequently, despite several uncertainties, the market of reuse is expected to grow significantly, but CBHs would only be a driver for this growth, an intermediate step, not the final solution in a circular economy.

Concludingly, CBHs are part of a fast changing alternative niche system that also includes regime practices. This alternative system contrasts the conservative regime of the AEC sector. CBHs and the practices that make up the system-of-practices in which CBHs reside should be perceived as a driving force for reuse, playing an important part in the transition. To make CBHs more successful in the short term, more focus should lie in aligning current regime practices with practices associated with CBHs. Further, contrary to how policymakers seem to adopt the concept of CBHs, they should not be perceived as the ultimate circular solution long term. For this practitioners place hope in a digital circular AEC sector, for which hubs can help pave the way. Visions of implementation of this digital built environment are important to allow these reconfigurations to happen.

There are several limitations to this research. First of all, perhaps most obviously, epistemologically, we cannot know the future for certain. The future practices discussed here should therefore not be perceived as a prediction, but as a starting point for change that can be discussed and critiqued. It should also not be interpreted as a single whole, but as a combination of futures of aspects that will influence each other and result in very different outcomes than the ones discussed in this article. Further, this explorative forecasting should be considered incomplete (e.g. the implementation of a digital built environment). Second, methodologically, the future practices discussed in this article stem from interviewees and participants that play a role in the system itself. They are therefore biased as their answers relate to their own future practices. Interestingly, many hub employees and architects were skeptical about their skills and role in the future. This made us trust the data more. Third, as this research focused on practices, we focused on developed practices we could observe, and not on hubs in development, as several public hubs are. Their different origins might lead to very different results from this research. Fourth, as there are currently few suppliers that deal in reuse of components, this research was limited in gathering data from these sources. Fifth, this research focused on a system-or-practices of CBHs, as it is assumed that this would provide a more sustainable future. However, the used theoretical framework of MLP and SPT is incapable of comparing systems-of-practices on sustainability (e.g. regarding the production of CO2).

As CBHs can form an important drive for reuse, and much is still unknown about the development of the system-of-practices in which they reside, they form an interesting topic for future research. Future research might particularly focus on hubs in different countries, or public hubs, as their different origins might help overcome some of the current barriers for reuse and result in very different practices. Further, this research might not only focus on the practices on and around

the hubs itself, but also on political practices, e.g. regarding space allocation. Also, future research might focus on suppliers that focus or aim to focus on reusing building components. Furthermore, future research might focus on changing regime practices regarding reuse (such as design, procurement, and supply), as this research shows that for the development of CBHs especially those practices are in need of reconfigurations. Lastly, future research might focus on digital technologies for reuse, regarding technique, implementation in practices, and governance.

This research highlights the systemic nature, nonlinearity, and uncertainty of the transition towards a circular economy. It shows that change can happen in practices, but for systemic change, the system-of-practices needs to change as a whole in a direction that is still highly uncertain.

Notes

1. Marktplaats is a Dutch online market platform, typically used for secondary components between consumers.
2. Insert is a Dutch online marketplace for secondary building components, public space components, and greens founded in 2018 as collaboration between private parties. Their core partners cover around 40% of demolition waste.
3. MPG stands for Milieu Prestatie Gebouwen, which is a Dutch procurement criterion, part of the building law, based on life cycle assessments.

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Data availability statement

Raw data were generated in the Netherlands. Derived data supporting the findings of this study are available from the corresponding author on request.

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