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The Barriers and Measures for Cascading Solid Construction and Demolition Timber:

The Business Ecosystem in Finland

Master's Thesis
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Abstract of master's thesis

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Abstract

Construction and demolition waste timber is mostly utilized for energy use in incineration plants in Finland, as it has been found to be better option both for the environment and in cost efficiency than otherwise recycling and processing the material. European Waste Hierarchy considers reuse to be the most preferred action after prevention. Cascading via reuse of solid timber could provide more efficient value capture and creation for the material and preserve timber as carbon repository. The thesis explores barriers and potential actions to promote cascading of C&D timber from the perspective of a business ecosystem.

The theoretical part explores and synthesizes the previous research around the literature of business ecosystem, circular economy and design and the particulars of cascading timber. The constructs of circular economy and business ecosystem contribute to the creation of conceptual framework that illustrates the relationships and roles of actors involved in the lifecycle of timber. The business ecosystem around the lifecycle of C&D timber consists of the forest industry, the construction sector and the waste management industry. The aim of primary research is to understand the needs, interests and overall situation of actors in the business ecosystem, which could be used to identify the existing constraints and potential solutions to promote cascading of C&D timber.

21 semi-structured interviews with industry experts from organizations within the business ecosystem and other involved specialists provide the necessary breadth for the qualitative analysis. The interview questions concentrate to understand the circumstances and level of collaboration between actors and to pinpoint the most relevant barriers and inefficiencies against cascading C&D waste timber by framing the issues to technical, legislative and economic attributes.

From numerous insights and opinions, the trend behind majority of technical and economic constraints revealed the most significant barrier against cascading to be profitability and cost efficiency. Lack of standardization for reused C&D timber and missing actors contribute to constraints as well. Reusing and recycling of C&D timber was mostly seen as desirable progress, but few could offer concrete solutions or see how they could advance it themselves.

The emergence of new actors such as pre-demolition auditors and material dealers would improve cascading of C&D timber. In long-term, design for deconstruction in timber products and buildings would enable more efficient reusing of timber material. Likewise, growth of wood construction will increase the relevance and economies of scale for reused material supply.

Keywords cascade, business ecosystem, C&D waste, circular economy, sustainability, forest industry, construction sector, waste management, waste hierarchy

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Rakennuspuujäte hyödynnetään suurimmaksi osin energiakäyttöön polttolaitoksissa Suomessa, sillä sen on todettu olevan parempi vaihtoehto kuin uusiokäyttö ja uudelleenprosessointi sekä ympäristön että hintakustannuksien kannalta. Euroopan jätehierarkia arvoi uudelleenkäytön olevan paras toimenpide jätteensynnyn ehkäisemisen jälkeen. Kiinteän rakennuspuujätteen uusiokäyttäminen voisi täten luoda korkeampaa arvoa materiaalille ja varastoida hiiltä. Tämä opinnäytetyö tutkii puujätteen uudelleenkäytön esteitä ja ratkaisuja bisnesekosysteemin näkökulmasta.

Teoreettinen osuus tarkastelee aikaisempia tutkimushavaintoja liittyen bisnesekosysteemiin, kiertotalouteen ja- muotoiluun ja puun kaskadikäyttöön. Bisnesekosysteemin ja kiertotalouden teoriat auttavat luomaan ajatusmallikehyksen, joka havainnollistaa toimijoiden rooleja ja suhteita puun elinkaaren vaiheissa. Puun elinkaaren ympärille sijoittuva bisnesekosysteemi koostuu metsäteollisuudesta, rakennussektorista ja ympäristöhuollon alasta. Tutkimustyön tavoite on kartoittaa bisnesekosysteemin toimijoiden tarpeet, intressit ja ja yleistilanne, mitkä voisivat auttaa puujätteen kaskadikäytön rajoitteiden ja mahdollisten ratkaisujen tunnistamisessa.

21 teemahaastattelua bisnesekosysteemissä toimivien asiantuntijoiden kanssa mahdollistavat kattavan ymmärryksen kvalitatiivista analyysia varten. Haastattelukysymykset keskittyvät ymmärtämään toimijoiden tilanteen ja yhteistyön tason sekä tunnistamaan olennaisimmat puujätteen uudelleenkäytön esteet ja tehottomuudet havainnollistaen ongelmat teknisten, lainsäädännöllisten ja taloudellisten ominaisuuksien puitteissa.

Runsaslukuisista ajatuksista ja oivalluksista, useimpien teknisten ja taloudellisten rajoitteiden takaa pohjimmaiseksi syyksi kaskadikäytön esteeksi osoittautui toiminnan kannattavuus ja kustannustehokkuus. Muita ilmiöön lukeutuvia ongelmia on uudelleenkäytettävän puun olematon standardisointi ja materiaalia hyödyntävien toimijoiden vähyys. Rakennuspuujätteen uudelleen- ja uusiokäytön nähtiin yleensä toivottavana kehityksenä, mutta harva kykeni mainitsemaan konkreettisia ratkaisuja tai miten he itse voisivat parantaa tilannetta.

Uusien toimijoiden syntyminen, kuten purkukatselmoijat ja materiaalivälittäjät, voisivat edistää rakennuspuun kaskadikäyttöä. Purkamisen huomioiva suunnittelu puutuotteissa ja rakentamisessa mahdollistaisivat tehokkaamman puumateriaalin uudelleenkäytön pitkällä aikajänteellä. Samoin puurakentamisen yleistyminen lisää uudelleenkäytettävän puumateriaalin saatavuutta ja merkitystä.

Avainsanat kaskadikäyttö, bisnesekosysteemi, rakennusjäte , kiertotalous, kestävä kehitys, metsäteollisuus, rakennussektori, jätehuolto, ympäristöhuolto, jätehierarkia

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1 Introduction

1.1 Background and the context of thesis

Sustainable development is becoming increasingly relevant in the industrialized world, where global concerns and challenges such as climate change, pollution of environment and resource scarcity remain still unsolved. Within this context, waste accumulation of about over 2,500 million tons of solid waste in the region of European Union member countries alone highlights the magnitude of the problem (Eurostat, 2015). The biggest single contributor to this number is construction and demolition waste (hereafter referred to as C&D waste), as it accounts for over one third of all waste generation in EU (ibid). Additionally, buildings and construction claim over one third of worldwide energy usage and despite the trend has been suggesting lowering energy consumption of per square meter of buildings over the current decade, it still falls short of the goals set in Paris Climate Agreement (Abergel, Dean and Dulac, 2017).

One approach to address these environmental problems has been the introduction of circular economy, which deviates from the standard linear lifespan of materials and energy flow that is considered wasteful from the perspective of sustainable development (Korhonen, Honkasalo and Seppälä, 2017). The concept of circular economy is still surrounded with somewhat limited academic research and technological challenges, despite being strongly promoted and acknowledged by governmental and business organizations (ibid). Nonetheless, several opportunities around circular economy in European Union have been recognized, including less imported resources and greenhouse gases produced and increasing amount of competitiveness leading to innovations and economic growth (Bourguignon, 2016). Yet, equal amount of obstacles to actualization of circular economy exists from limited governing, financial and economic steering and lacking skills and appropriate business models (ibid).

Construction of housing and infrastructure uses about 42.4 billion tons of resources annually in global economy, which is about 40% of the extracted resources per year (de Wit et al., 2018). This places a huge burden on the environment and one estimate suggests that over two thirds of greenhouse gas emissions in the world are contributed to material management, as only 9.1% or 8.4 billion tons of material was cycled according to global circularity metric (ibid). Thus, the importance of adopting and advancing circular economy principles to industries is tremendous to preserve sustainability and ensure sustainable business.

Finland is still far behind from other EU member countries with its C&D waste recycling rate of 26%, whereas the average rate among the member countries is about 47% and top performers such as Denmark and Netherlands are able to reach even rates of over 90% (Ympäristöministeriö, 2014). Although, the reported results from some of the countries may be unreliable, the biggest contributor to the middling result of Finland has been considered to be the relatively large share of wood-based C&D waste material that has been problematic due to evaluating the quality of the material and thus are mostly utilized only for energy use (ibid). One estimated amount of waste timber material generated annually was 850 000 tons of which over three fourths originated from construction and demolition waste streams (Pirhonen et al., 2011). In addition, over 2.7 million tons of wood waste (94% of total) was estimated to go to energy use in the year 2015, while only around 0.18 million tons (6% of total) went to material recovery (Statistics Finland, 2017). However, EU waste directive has stated an ambitious target of having 70 weight percentages of reusing and recycling safe C&D waste material, which would most likely also necessitate improved recovery rate of wood material (Ympäristöministeriö, 2014).

Since the forest land areas in Europe have increased starting from the early 1990 and the renewal time required for timber resources is relatively short in comparison to alternative construction materials, timber should be perceived as the most sustainable construction material if not even the only sustainable building material (Ramage et al., 2016). Yet, several developing countries have still unsustainable forest harvestry causing eradication of forest areas enough to have global net loss of area (ibid). These ecologically vital forest regions could also be preserved by shifting from imports of timber to cascading C&D waste timber for construction elements and other purposes.

Some of the forerunner countries in the European Union like Netherlands have already established principles of cascading solid wood material to their policies, as the regulators have slowly started to recognize that concentrating solely on bioenergy initiatives does not support sustainability principles enough (Sokka, Koponen and Keränen, 2014). Despite these efforts much ambiguity is left in the field, since even cascading as term has not managed to solidify an exact definition (Fritsche and Iriarte, 2014). However, most sources seem to agree that the goal of cascading practices is to drive resource efficiency by reusing and recycling material before the energy of disposal stage (Fritsche and Iriarte, 2014; Koistinen, 2016). Therefore, cascading could be considered as a term and practice under the larger entity of circular economy (Korhonen, Honkasalo and Seppälä, 2017).

Business ecosystems is likewise as a concept still suffering from ambiguity in its exact definition, but some of the topics and concepts that it relates to are "self-organization, co-evolution, emergence, and adaptation" (Peltoniemi and Vuori, 2008, p.2). Thus, business ecosystems literature seems to have applicable approach to enable analyzing the organizational environments and their networks around potential cascading wood practices in order to comprehend each of their relationship and motivations.

Cascading timber related research and business ecosystems literature along with lifecycle thinking are explored, analyzed and synthesized in the literature review to frame the overall ecosystem setting and help to identify the essential actors and factors that either contribute or prevent the adoption and spreading the cascading wood practices. According to a survey of real estate and construction industry stakeholders, the most common perceived barrier is the minimal or even nonexistent economic benefits of sorting and recycling (Ympäristöministeriö, 2014). Furthermore, the feasibility of cascading both from economic and environmental perspectives seem to have a scarcity of current research available

(Sakaguchi, Takano and Hughes, 2016), which provides an ample opportunity to explore and expand further in this topic.

The purpose of this thesis is to explore the business ecosystem related to cascading solid C&D timber waste practices in Finland and how to enable and increase cascading of C&D waste timber. This thesis is part of a multidisciplinary research project called "Rewood" that is setting the groundwork for enabling wood cascading principles. The non-academic objective for the thesis is to identify the current constraints and challenges regarding the business ecosystems around cascading wood and explore the potential pathways to mitigate those problems whereas the academic ambitions of this paper lie in filling the research gap of understanding and analyzing the industry actors from business ecosystem perspective through a qualitative research approach.

1.2 Research Gap

Pomponi and Moncaster (2017) suggested for further research to inspect ways how to have technical solutions adopted within societal dimension as well as to examine the environmental and economic viability and policies for circular economy practices in buildings. Furthermore, Ramage et al. (2016) has identified several related research topics around cascading solid timber to be explored further, which include designing buildings that implement easier disassembly and how to achieve reuse and sorting of C&D waste solid timber material to be both environmentally sustainable and economically profitable and what kind of policies should be enacted to enable these changes to shape.

Business ecosystems literature, on the other hand, has been found to mostly concentrate on high-technology industries (Peltola et al., 2016). Additionally, Ben Letaifa (2014) suggests further research for how to utilize and leverage the collaborative capabilities of actors in business ecosystems. Thus, applying business ecosystem thinking to different fields with their own intricacies, such as construction industry, could provide new insights on the applicability of business ecosystem approach on a more general level.

1.3 Research Objectives

Based on the identified gaps and brief background introduction, the primary research question is:

RQ1. How should business ecosystem consisting of the forest industry, construction and waste management sectors in Finland be restructured to mitigate the current barriers for cascading C&D waste timber?

The supporting secondary research questions that help to answer the primary research question are:

RQ2. What are the barriers for more efficient cascading of C&D waste timber?
RQ3. Why are the relevant actors related to C&D waste timber using their current practices?
RQ4. How could the lifecycle of C&D waste timber be extended from its primary use?

Cascading C&D waste timber is still practically nonexistent in Finland. Collaboration of business ecosystem actors could be a prerequisite for enabling cascading C&D waste timber. Through identifying actors' position and interests, their activities could be aligned to yield optimized and efficient business ecosystem that utilize the best practices for cascading C&D waste timber.

1.4 Structure of Thesis

The literature review of this paper analyses and synthesizes existing literature by concentrating on identified key topics and concepts related to the formulated research questions. These explored topics are cascading timber, sustainable construction and demolition, business ecosystems, circular economy and design, lifecycle thinking and related policies. The topics are first explored separately to better understand their role and relation to the research questions and these are then used to develop conceptual framework that aims to give coherent view of the circumstances and relevant factors for business ecosystem and cascading timber. The following section explains the methodology to be used for the qualitative primary research. The findings will analyze the data and results extracted from the qualitative interviews, which are then discussed to derive meaningful knowledge and concepts.

2 Business Ecosystems, Circular Economy & Cascading Timber: Literature Review

2.1 Business Ecosystems

Moore (1993) seems to be the first one to introduce the concept of business ecosystems in which biological ecosystem analogies are reflected on a business environment, where companies are perceived as part of several industries that enable the leveraging of innovation networks under dynamic systems. Four subsequent stages of business ecosystems that were identified start from birth, continue with expansion, after which leadership is maintained and finally necessary self-renewal to ensure the relevance of business ecosystem (ibid). Since cascading wood practices have not gained traction at the moment, the most applicable stage for business ecosystem around it would be either birth of a new ecosystem or self-renewal of old business ecosystems that would innovate the cluster of current and new ideas in co-evolution with network partners.

However, Moore's view seems to emphasize that business ecosystems usually have a leader, around which other companies flock to provide value in the chain and fill in the niches to build the ecosystem (ibid), which shares similarities with the concept of keystone organizations that are central to an ecosystem and support other organizations to their own advantage (Iansiti and Levien, 2004). The successful coordination of the life stages seems to determine which companies succeed in claiming the leadership. On the other hand, the business ecosystem literature in general seems to acknowledge ecosystems to have decentralized control, where all the actors have limited knowledge base and capability to influence the rest of ecosystem (Peltoniemi, 2004). Indeed, the actions of one company can affect the performance and health of other companies both in and outside of their industry (Iansiti and Levien, 2004). Iansiti and Levien (2004) framed an analogy conforming criteria of health in both biological and business ecosystem that are productivity, robustness and niche creation, which could help to illustrate the actual state of an ecosystem. New organizations adopting niche strategies could provide new kind of solutions also to the business ecosystem around cascading timber.

Business ecosystem model and thinking shares many similarities with cluster and value network models, but some of their identified main differences include that cluster aims to assess systems from more geographical and rivalry perspective, whereas value network focuses on co-operation of nodes, while business ecosystem has more holistic approach of considering both aspects of business (Peltoniemi, 2004). Also, the cluster and value network are limited by the concept of industry, whereas the very idea of business ecosystems is to discard myopic view of industry, but have the ecosystem thinking replace it as complex system of interconnected actors (Moore, 1993; Peltoniemi, 2004). Another important difference is the embedded thinking towards innovation in the three models, where cluster and value network actors are constrained by the limitations of industry and role in the network respectively, while business ecosystem seems to embrace an absorptive innovation strategy to support the co-evolutionary processes of actors (Peltoniemi, 2004). Considering the cascading wood practices, business ecosystem model would seem to hold the most promise to innovate the relationships of related actors and sectors.

Curley et al. (2013) point out the complexity of innovation in organizations and lack of innovation ecosystems frameworks. However, investing in open innovation partnerships have been indicated to lead to better financial performance in R&D projects with appropriate project management methodologies (Du, Leten and Vanhaverbeke, 2014), which could prove beneficial also in innovating new solutions for cascading wood. However, this approach could prove too complex and in-depth as such exploration could necessitate exploration of systems from individual layer to organizational and socio-economic layers (Curley, Donnellan and Costello, 2013). Industrial ecosystems seem to also share similarities with business ecosystem, but instead of considering network of actors, industrial ecosystem is concerned with minimizing waste and maximizing production efficiencies (Peltoniemi and Vuori, 2008). Liu, Ma and Zhang (2012) analyzed sectoral boundary as primary reason to prevent value creation and recognized governmental intervention as key stage to enable industrial ecosystem.

Korhonen (2004) advocates industrial ecosystem approach for strategic sustainable development. Fig. 2.1.1. visualizes the idealized situation of industrial ecosystem where positive outcomes are reached on environmental, economic and social level. Thus, the collaboration of actors in an ecosystem could potentially create gains on multiple levels. However, this is just ideal situation as mentioned, whereas in reality several obstacles and considerations exist, such as that too diverse ecosystem tends to have too many interests that are bound to conflict (ibid).

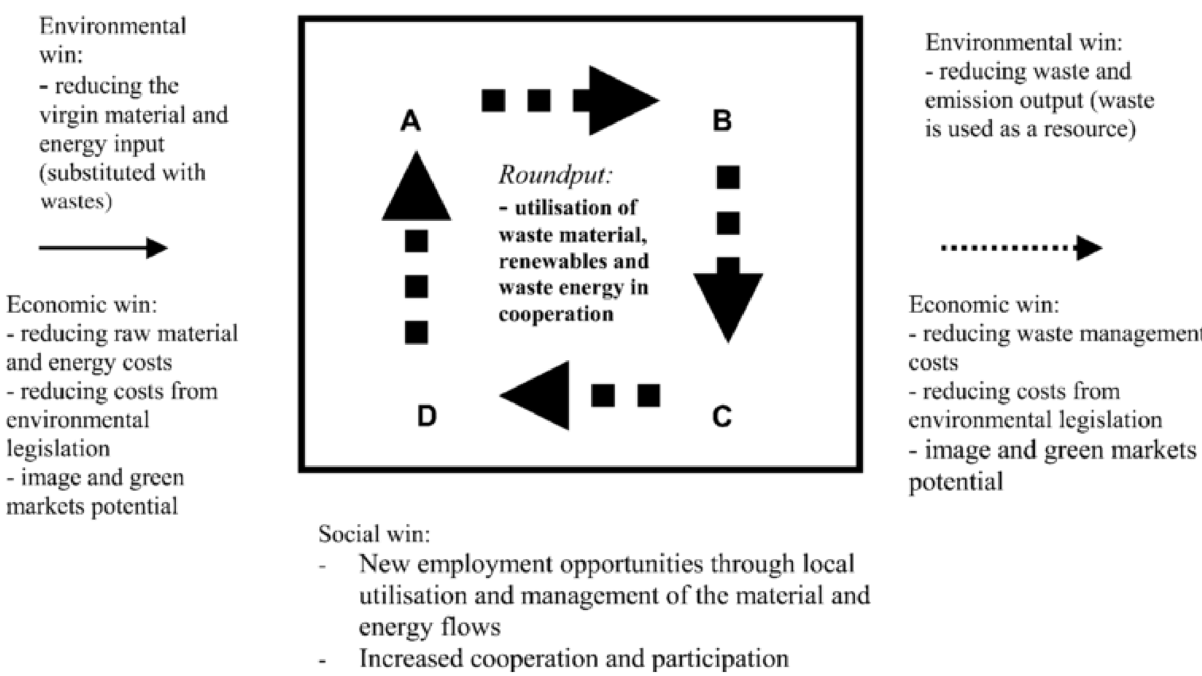


Figure 2.1.1. Industrial Ecosystem and opportunities of win-win-win situation (Korhonen, 2004). A,B, C and D represent industry actors.

One proposed method for better configured business ecosystem is backcasting, where the vision starts from the future state, where the organizations would want to be after successful outcomes, which is used to build the steps to reach that goal (Korhonen, 2004).

Such mode of thinking along with applicable metrics and monitoring could bring ecosystems closer to the desired ideal state (ibid).

Rong et al. (2015) suggests the use of a 6C framework to clarify and structure the concept of business ecosystems, which are analyzed through the lens of three groups of which first consists of context and cooperation for assessing ecosystem lifecycle, while second group has construct, capability and configuration to portray the current view and lastly the third group entailing the change that allows to view the evolution of ecosystem environment and its technologies. However, as the framework has been assimilated for IoT-sector, its applicability for other business ecosystems is undetermined, but such more methodized approach could provide better insights to map the potential and challenges in business ecosystems.

In another study, Rong et al. (2013) links platform strategy to business ecosystem life cycle by identifying platform to incorporate interaction interface, value creation and network formulation to the business ecosystem and viewed business ecosystem from levels of organization, technology and application (or rather services outside the context of IT-platforms). Within the business ecosystem lifecycle, three platform strategies for appropriate life cycle stages were determined, where open platform is suitable for birth phase, dominating platform strategy suits best at leadership/authority stage and opportunistic platform strategy seems to be applicable for renewal stage to search for new sources of revenue (ibid).

Pomponi and Moncaster (2017) suggest based on findings from practice that the main barrier preventing circularity is not technical, but the change is led by social and behavioral stances of people. Thus, applying business ecosystem thinking to the sectors involved for cascading solid timber suggests great potential findings. However, past experiences have indicated that cross-sectoral councils and collaboration have yielded negligible returns, as all actors are protecting their own interests in solving environmental problems, thus leading to solutions with easy compromises (Zaccai, 2012). Win-win situation for all stakeholders seems to be infeasible approach to tackle problems such as how to establish cascading solid timber practices to become profitable. This dilemma seems like a potential and essential topic to explore further for the business ecosystem around cascading timber, and how the ecosystem should be reconfigured to diminish the negative impacts from changing the dynamics of industries.

Peltola et al. (2016) employ concepts of "value creation" and "value capture" in their comparative analysis of business ecosystems for municipal solid waste management to investigate roles of key stakeholders. These concepts relate business ecosystem to value network identifying the complexity of stakeholder relations in a supply chain and recognizing their involvement in multiple value networks and possibly even in different roles (ibid). Hence, the concepts of business ecosystem, value network and supply chain could be considered to embody interlacing qualities. Fig. 2.1.2. helps to illustrate the stages of business ecosystem development that reveals how ecosystems tend start with high collaboration, but end up divided into silos. This could hypothetically imply that business ecosystem related to cascading solid timber is currently in ecosystem development stage with low value creation and high value capture, which means a new cycle of ecosystem creation will be required in case of disruption in the markets to engage the formation of a new business ecosystem.

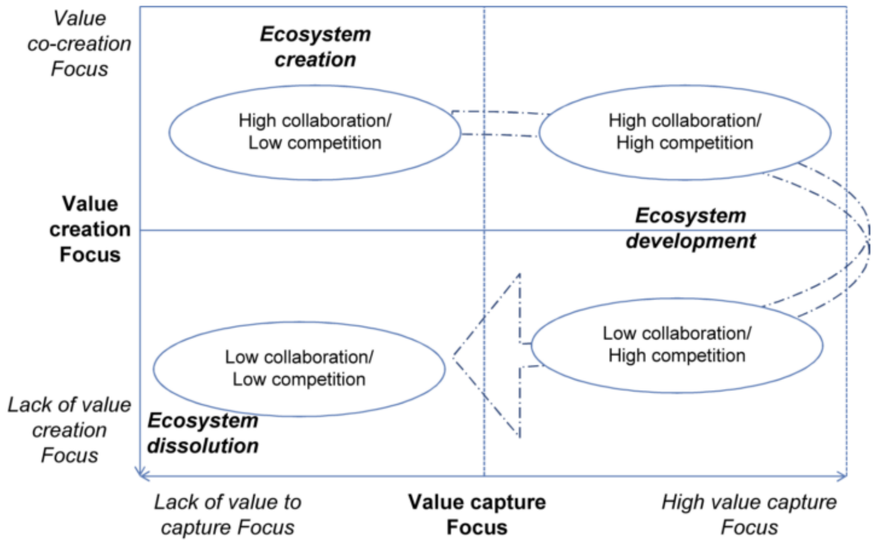


Figure 2.1.2. Business ecosystem development stages and their sequence(Ben Letaifa, 2014).

The waste management business ecosystem in Finland seems to be devoid of the business ecosystem wide processes to capture the value of waste streams and sorting (Peltola et al., 2016). A few bigger companies in the waste management business ecosystem were identified as key stakeholders in Finland that have stronger influence in the ecosystem (ibid). Therefore, collaboration of these key stakeholders could open new possibilities also for the more specific case of reusing solid C&D waste timber.

Iansiti and Levien (2004) define the business ecosystem to consist of a multitude of various actors, including suppliers, distributors, competitors, companies to which processes are outsourced to or are financed, companies providing technology, assets or complimentary services or products contributing to the ecosystem, customers, media and regulators. Basically, business ecosystem entails everyone that directly or even indirectly affects the activities such as value creation and capturing in the ecosystem. Antikainen et al. (2017) identify several key actors and two industries for wood construction in Finland. The actors include sawmills, wood product manufacturers and building element manufacturers on forest product side and construction companies, real estate investors, architects, designers, municipalities, researchers and regulators on construction industry (ibid). An assumption can be made that these correlate directly with the business ecosystem for cascading timber.

2.1.1 Value Network, Clustering and comparison to Business Ecosystem

Whereas business ecosystem is concerned more with the industrial environment and the formed relationships, value network concentrates on the movement and exchange of value; tangible values of goods, services and revenue, knowledge and intangible benefits akin to goodwill (Allee, 2000). Hence, a business ecosystem can contain several kinds of value networks. Ben Letaifa (2014) argues that established work silos around value chains have become outdated and impractical in the context of current interconnected societies. The author would argue that to stimulate cascading wood to gain traction as a widely adopted practice, the consideration and analysis should not be merely limited to goods in the form of timber, but rather to acknowledge and integrate also these other modes of value to enable wood cascades.

The overall trend seems to be that companies and industries have been shifting to transform from the traditional linear thinking of value chains to more complex exchanges of value among networks (Allee, 2000). However, contradictions of interests exist among interactions of value creation, as in ecosystem perspective for collaboration, and value capture, as in value chain perspective to attain economic gain that also creates a rift of thinking in concepts of interdependence, cooperation, vision and leadership (Ben Letaifa, 2014). Thus, the challenge to solve the improved functionality seems to depend on how to merge this dichotomy in social discourse of attitudinal approach between organizations and people.

2.1.2 Innovation Ecosystems

Not much literature has been produced yet around the relationship of technology and innovation management despite its acknowledged important role (Van Lancker, Wauters and Van Huylenbroeck, 2016) that could seemingly enable the pathways to more sustainable practices. Instead, Van Lancker et al. (2016) recognize that the academic scientific literature pertaining to bioeconomy concentrates more towards examining technical processes and their possible environmental impacts. This suggests potential research gaps regarding bioeconomy and the means of ideation and development of new innovations that could be scrutinized further.

Some of the identified key factors impacting innovation in bioeconomy industries include entirely new and potentially disruptive innovations ranging from anywhere of business models to processes that are driven by increasing collaboration of actors and generation of rich and complex knowledge bases that enable commercialization often enforced under the jurisdiction of various policy frameworks which contrivances pose additional challenges in firm-levels (ibid). The suggested approach amidst such environment to tackle and turn around the challenges and boundaries to advantages has been to bridge the fields of knowledge via transdisciplinary cooperation to drive the delivery of new ideas and innovations (ibid). Thus, this would require for various actors in a business ecosystem to work together to find the appropriate and most viable solutions to problems (Levänen, 2015); such as enabling cascading wood practices to permeate the industries. Additionally, collective learning would require stronger meshing of industry actors and regulatory bodies (ibid).

Furthermore, Van Lancker et al. (2016) recognizes the iterative process for innovation in bioeconomy to be the most valid approach, which involves terms and elements such as feedback loops, reverse flows and interconnectivity. Such description conveys similarities to the concept and descriptions of systems thinking (Kim, 1999; Adams and Cavana, 2009). Looking through the lens of a firm within an industry, Van Lancker et al. (2016) classifies seven different classes of stakeholders that could contribute to innovation process to varying degrees in the three phases of idea generation, invention and commercialization. These stakeholder classes are policy makers, competitors, academic and research organizations and consultants, users and customers, suppliers along with other actors in the value chain and even organizations from seemingly unrelated industries (ibid). These stakeholders should then be optimized in a layered network management process to support efficient collaboration of actors at the appropriate phases of innovation process.

2.2 Lifecycle Thinking

The economic incentives to enable circular economy are still missing, as production of more durable goods is more expensive when external costs do not have to be taken into consideration (Sauvé, Bernard and Sloan, 2016). One approach to tackle the problems of circular economy could be eco-design along with life cycle analysis to perceive potential ways to decrease environmental impacts in different stages of a product (ibid). As such, the design of a product and its production could have an important role to reduce the amount of waste and enable more efficient reuse and remanufacture of the product, but if the companies designing the products lack the incentives to strive their attention towards those goals, they are unlikely to make additional investments towards it while compromising the bottom line of the company. Both life assessment and material flow analysis have been accepted as suitable tools to portray the relation and potential of system from economic, technical and environmental perspectives (Pomponi and Moncaster, 2017).

Life cycle assessment (LCA) is supposedly the most common method to measure environmental impact of cascading wood (Thonemann and Schumann, 2016). The purpose of LCA is to measure and evaluate both material and energy flows, which standardized procedure consists of defining scope and goal for definitions, life cycle inventory for quantification of inputs and outputs of a system, assessment for environmental impacts and finally draw interpretations and analysis of the previous stages (Ramesh, Prakash and

Shukla, 2010). Due to lack of standardization in production processes in the construction industry, conducting LCA is could be considered more challenging than in many other industries (ibid). Additionally, it seems that there is a lack of especially quantitative research regarding the measurement of resource efficiency in cascading wood (Thonemann and Schumann, 2016). Thus, the actual impact of cascading on environment remains still unclear.

Ligthart and Ansems (2012) also explain LCA methodology to consist of four phases which are defining goal and scope via formulating exhaustive research question, carry out inventory analysis, assessing environmental impact and finally interpreting the data and results, since many factors have to be considered when conducting complex LCA studies. Furthermore, despite reuse is considered the most optimized end-of-life scenario (ibid), few studies seem to include this aspect in their analysis due to added intricacies. One of the reasons for these intricacies is that new and old material is mixed in a new cycle and C&D waste material faces usually multiple scenarios at once to varying degrees (ibid). Lighthart and Ansems (2012) identify three different schemes for recycling that are closed loop (reused or recycled for same original purpose), open loop (recycled for different purpose) and semi-closed loop (reused for new purpose) and LCA also has several allocation procedures to address recycling. While system expansion, as in creating closed loop, seems to be the preferred method of ISO 14044 guidelines that standardize LCA methodology (ibid), the most suitable allocation method for solid C&D waste timber could be economic allocation that addresses viability of recycling by considering material flow to be connected to economy and its constraints.

The global economy has made sustainable development challenging as lean production and scales of economy have made product parts and components to be developed in the most cost-efficient location which on the other hand cannot be considered eco-efficient (Braungart, McDonough and Bollinger, 2007). In the context of such environment, eco-efficiency goal of reaching no waste emissions and resource use is infeasible, but shifting from cradle-to-grave material flows to cradle-to-cradle flow metabolisms, where materials flows are closed to regenerative loops, could bring numerous opportunities (ibid). Eco-effectiveness rejects life cycle assessment (LCA) as ill-suited, as it is primarily designed to account for environmental impact in linear life cycle, and instead supporting strategies for eco-effectiveness include for example "cradle-to-cradle design, positive lists, intelligent [and] materials pooling" (Braungart, McDonough and Bollinger, 2007, p. 11). In relation to this, triple top line acknowledges environmental and social aims through aims of business objectives in contrast to triple bottom line (ibid).

Even though eco-efficiency could be considered to have too little impact to environmental sustainability, it still seems to be one of the more feasible and utilizable approaches for sustainability. Material efficiency in the all stages of lifecycle is one aspect of eco-efficiency to reduce C&D waste and otherwise prevent losing material, but transportation and energy consumption over the building utilization also contribute to ecological burden (Hradil et al., 2014). In this context, the longest distance to transport C&D timber material for reuse would be 1600 km (ibid). Kaziolas et al. (2015) performed lifecycle analysis to timber building along with statistical methods such as genetic algorithms and simulated annealing to minimize the costs that would lead to more efficient use of timber while also considering the energy performance of a building, which exemplifies the benefits of analytics also to design of building by taking the whole lifecycle into consideration along with reuse and recycling costs.

Ramage et al. (2016) mentions that previous studies have found degradation of timber, or even building material in general, to be quite rarely the reason for demolition. This could provide the implications that cascading old solid timber material for new buildings is feasible from technical viewpoint, as long as the design of building takes into account the threat of moisture that could deteriorate the properties of timber.

2.3 Circular Economy

The circular economy represents a paradigm shift from the traditional view of strict interrelation between economic growth and depletion of resources, as circular economy thinking postulates that economic development can and should exist without burdening the environment (Pomponi and Moncaster, 2017). Pomponi and Moncaster (2017) developed a research framework for circular economy forming a holistic view of the concept that consists of six dimensions, which are governmental, economic, technological, environmental, behavioral and societal. The framework also acknowledges the equal importance of top-down policymaker approaches and bottom-up grassroots innovation in driving circular economy forward (ibid).

Waste hierarchy seems to be one of the more influential doctrines of theory among the sustainable development of materials that has affected academic research, industry practices and legislative measures. Essentially, waste hierarchy sets basic guideline and the priority of order in actions to minimize the amount of waste generation (Meinander et al., 2012). Starting from the most preferred towards the last option, these actions are, reduction, reuse, recycling (preferably as material, secondarily as energy), which combined are more familiarly known as 3 R's of waste management, and finally, disposal (ibid). This basic abstraction is also the premise of circular economy, although the terms vary depending of the source (e.g. reuse, remanufacturing, recycling and disposal (Korhonen, Honkasalo and Seppälä, 2017) and concept of circular economy forgoes reduction of material aspect as self-evident and as an individual concept that only works to decelerate the problem rather than trying to solve it. Rather, reusing and recycling by themselves serve to reduce the use of new virgin materials and decreasing the amount of disposable waste in incineration or landfill (Andersen, 2007). Thus, the emphasis on driving change towards circular economy and sustainable development would be to advance reuse of materials.

Since economic efficiency was brought up as an issue already in the introduction, Andersen (2007) points out that recycling and reusing will only happen when it is considered profitable in the current economic system and suggests environmental economics consisting of four functions that are known as amenity values, resource base for economy, residual waste sink and life-support system that enables life on Earth to begin with. Economic activities tend to cause external effects that are usually negative and harm these four functions, yet it is difficult to quantify and valuate these effects and so far the best method to do so has been life cycle assessment (LCA) that enables to estimate the external costs (ibid). Utilizing these external costs to set an external taxation system could prove to be necessary incentive for companies to strategize and invest in new alternatives to regain cost efficiencies while contributing to more sustainable economic activities (ibid). This addresses the RQ1 directly, as companies involved in large-span structures could become more interested to adopt cascading wood practices to decrease the amount of their external costs.

Many challenges and constraints to truly realize circular economy in reality still prevents its proliferation and integration to the current economic systems. Some of these are physical and thermodynamic limitations, – that might hinder the efficiency of recycling, but once again highlights the priority of reuse and remanufacturing – laws of economic efficiency that drives consumption further as costs decrease and questionable sustainability of building new infrastructure to support circular economy (Korhonen, 2004; Korhonen, Honkasalo and Seppälä, 2017). However, in terms of cascading wood, the more direct imposing impact might become from already established governance and management practices and locked-in technologies and the existing social notions and ideas about waste (ibid). In other words, current economic environment, technological praxis and societal systems may be difficult and time consuming to modify to reflect the ideology and practices of circular economy.

In the triple bottom line approach of looking from economic, social and environmental aspects, successful implementation of circular economy could bring numerous advantages. Both the economic and environmental perks stem from reduction, as the economic aspects arise mostly from the economic perspective of reductions in resources, energy and waste management in addition to new business opportunities and greener brand image, while environmental gains come from reduction of natural resources, waste and emissions (Korhonen, Honkasalo and Seppälä, 2017). Thus, circular economy and the reuse of materials by themselves are drivers of reduction. The social aspect on the other hand holds a promise of new types of jobs and communities revolving around sharing (ibid). Nonetheless, some view triple bottom line strategies unrealistic as economic needs are considered the priority and environmental impact is usually considered as secondary objective (Braungart, McDonough and Bollinger, 2007). Additionally, several researchers and their circular economy frameworks have left the role of policies, design and behavioral factors to superficial level in their view of the triple bottom line thinking (Pomponi and Moncaster, 2017). Ultimately, the conundrum around circular economy would seem to be the divide between designers' endeavors for greater diversity and sustainability, while economic view concentrates on how to scale the new thinking and solutions to make them profitable (ibid).

Multitude of frameworks and methods to resource recovery for waste exist already, but most of them seem to explore the issue from rather narrow perspective, concentrating only on one area or make ungrounded assumptions to validate their frameworks, whereas a more comprehensive and holistic view is required to understand the various incentives and barriers that affect involved stakeholders (Iacovidou et al., 2017). Such framework would involve all the four overlapping domains of technical, economy, environment and social – not to forget political assessment embedded within the four domains – which would help to create a narrative framework, where the entire system from actors to processes and structures would be analyzed (ibid). At the moment, environmental metrics, such as life cycle assessment, are the most common to be used, whereas social metrics are the rarest type to be used, which could suggest low level of involvement from social scientists towards waste resource recovery related research (ibid). Formulating a new holistic framework involving the four domains could provide beneficial insights when exploring cascading wood ecosystems.

In terms of applying circularity to buildings, one of the main challenges becomes apparent when considering the existing old buildings and their limitations, as they can render new technological solutions infeasible to implement due to the constraints of the buildings (Pomponi and Moncaster, 2017). This calls for an approach that considers the challenges and possibilities from the perspective of the current stock of buildings in addition to conjuring new innovations for future buildings.

2.4 Circular Design

Hradil et al. (2014) consider designers to have the most significant role to enable reuse of material and thus, cascading timber with instructions and documentations and proper storing of this information. However, designers likewise require information of available reusable elements for them to be able to utilize available resources. Interestingly, building owners and investors are seen to be as vital to realize reuse projects, since these stakeholders are on top in the line-of-command (ibid). In fact, designers should take into consideration the whole business ecosystem, when designing new products or services, so that it supports and connects to the services of other organizations (Iansiti and Levien, 2004).

Digitalization and various applications provide further opportunities to support and even lead design processes necessary for circularity and reusing construction waste. One often mentioned digital process seems to be BIM (Building Information Modeling) that is deemed essential to facilitate distribution of building elements (Hradil et al., 2014). Furthermore, LCA provides the opportunity to consider sustainability already in the design phase of a construction (Korhonen, 2004).

The approach to plan and construct buildings for easy deconstruction has been dubbed as design for deconstruction (DfD) (Hradil et al., 2014). Pertaining axioms for DfD prioritize to reuse of material for its original purpose, followed by other repurpose and only after that recycle the raw material to something else (ibid).

The main principle behind DfD emphasizes the separation of all components according to the length of their lifecycle and how they are to be reused or recycled (Hradil et al., 2014). The purpose of this is to minimize the duration to deconstruct which in turn leads to economic savings in the process. The supporting principles to achieve this DfD are modular building, easy disassembly and dismantling for frame and joints, smart material selections such as using only one material per module and avoiding hazardous materials and conducting deconstruction plans in advance (ibid). Modular timber elements are suggested to have several benefits such as "reduced waste, lower costs, and shorter installation programs" (Ramage et al., 2016:345). Modular approach to construction seems to be already widespread practice, as timber construction elements are usually processed industrially as either panels or modules and then just shipped to construction site for assembly (Malesza and Miedziałowski, 2017).

The most vital role to implement DfD to a building is not only with the architect, but also with the client as in building owner and the technical experts involved in the construction such as structural engineers (Hradil et al., 2014). Yet their implementations may be infeasible unless manufacturers of building elements start to develop their products to be easily reused (ibid). One positive example of promoting new kind of wood-based construction is Open Source Wood Initiative by Metsä Wood, where modular wood design solutions are co-created in an innovation platform (Metsä Wood, 2017).

One of the main obstacles preventing the reuse of material and deconstruction practices is that they are deemed unprofitable (Hradil et al., 2014). One way to prove the actors concerns wrong would be to conduct successful short lifecycle case examples such as hangars or schools as demonstrations of these practices viability (ibid). Proposed actions to drive profitable business of buying and selling reusable C&D waste elements is to have early enough identification and planning of deconstructable buildings and ensure the conformity of the available elements for different purposes (ibid). For that reason, Finnish regulatory bodies have advocated for actors in waste management sector to implement technological advancements that would enhance the value capture of waste material (Peltola et al., 2016).

A case study of implementing circular economy and design to building sector identified visions of future, learning of actors, network dynamics and business model innovation as key concepts to actualize new form of collaboration between actors in the building supply chain, where one of the involved buildings was labeled as the first BREEAM certified demolition project (Leising, Quist and Bocken, 2017). Especially regarding network dynamics, the paper mentioned potential elements contributing to relationships, such as trust, cross-functional activities within and between organizations and organizational support for new initiatives and three main factors involved that are actors, available resources and the activities to generate, exchange or combine these resources (ibid). Hence, their lens through which they inspect construction projects is strikingly reminiscent of value network, although the paper tends to refer more to industrial network theory (ibid). In this study, the interview of actors in the supply chain was limited to those directly involved with a building, including developer, architect, contractor, demolition, and end-users, which may neglect the effect of stakeholders earlier or later in the supply chain that may have an influence in the overall design and both economic and ecological values of the buildings.

An interesting aspect that affects both the design and business model around construction was imposed to one of the buildings by having the suppliers retain the ownership of their materials even when installed to the building to encourage easy disassembly (Leising, Quist and Bocken, 2017). This advocacy for shift in business model to service-based has gained a lot of traction also among academic articles (Pomponi and Moncaster, 2017). Such system applied to solid timber elements could potentially encourage the actors consider deconstruction already before the construction phase starts. The collaboration of actors in the construction was applied likewise in an innovative way by having collective multi-disciplinary collaboration of an architect, a developer, interior designers, a contractor, building installation advisors and companies in a one "construction team model" that work together to prepare for the construction (Leising, Quist and Bocken, 2017). The developer was identified as a key player to connect the team together which was elevated by trust between actors that had worked together before and reassurance that all would be allowed to join for future collaborative efforts (ibid). Interdisciplinary approach has been identified as a way to advance circularity in buildings in a way that would retain technical aspects while addressing various other dimensions (Pomponi and Moncaster, 2017).

Another sustainable renovation project discarded the traditional approach of identifying the requirements for the project and instead mapped the needs of client and end-users to determine how the building should be renovated (Leising, Quist and Bocken, 2017). Since cradle-to-cradle building was one of their ambitions, C&D waste was reused, and of that, solid timber was reused for the facade of the building, which was enforced by applying new rules for tendering process that advocated for reusing C&D waste as building material (ibid). Indeed, change in tendering priorities from the cheapest alternative to more open collaboration between contractors has been advocated by academic literature as well (Pomponi and Moncaster, 2017).

The importance of collaboration and trust seemed to be a common theme that elevated the efficiencies of these building projects. Yet, while several analytical tools are available to analyze and grade the level of sustainability in a technical level, there is a lack of organizational tools that would encourage the collaboration necessary to make these kinds of projects viable. The difficulty of implementing collaboration for circular economy in the whole supply chain was recognized, accentuated by the wrong kind of economic incentives (Leising, Quist and Bocken, 2017).

2.5 Cascading Timber

The definition of cascading wood refers to using wood from one product again in another purpose, where in single-stage cascade the second use is straight for energy, but in multi-stage cascade the wood has to be reused at least once again in some product before going to energy use (Vis, Mantau and Allen, 2016). Their final definition for cascading after comparison of definitions and allowing some breadth for the term is as follows: "Cascading use is the efficient utilisation of resources by using residues and recycled materials for material use to extend total biomass availability within a given system" (Vis, Mantau and Allen, 2016:201).

The factors stated to affect ability to cascade in countries are the capacity of forests and the forest industry, economic situation contributing to the consumption of forest-based products and also the level of material and energy uses of the material (Vis, Mantau and Allen, 2016). Consequently, Nordic countries such as Finland possess large quantities of forest biomass available that lead to high production, but cascade rates of material are lower than in any other part of Europe (ibid). Overall, the report by Vis, Mantau and Allen (2016) seems to be one of the most encompassing and exhaustive studies on cascading timber, which inspects and analyzes the current situation, barriers and solutions to cascading timber in EU. Figures 2.5.1. presents some of their key findings regarding the potential in optimizing cascading of timber by mapping various barriers and solutions to them over the timber material flow. The illustration helps to highlight that the barriers to cascading timber are not reduced to a single bottleneck, but instead multiple constraints and inefficiencies exist over the value chain and lifecycle of timber.

Figure 57: Barriers to cascading and potential solutions

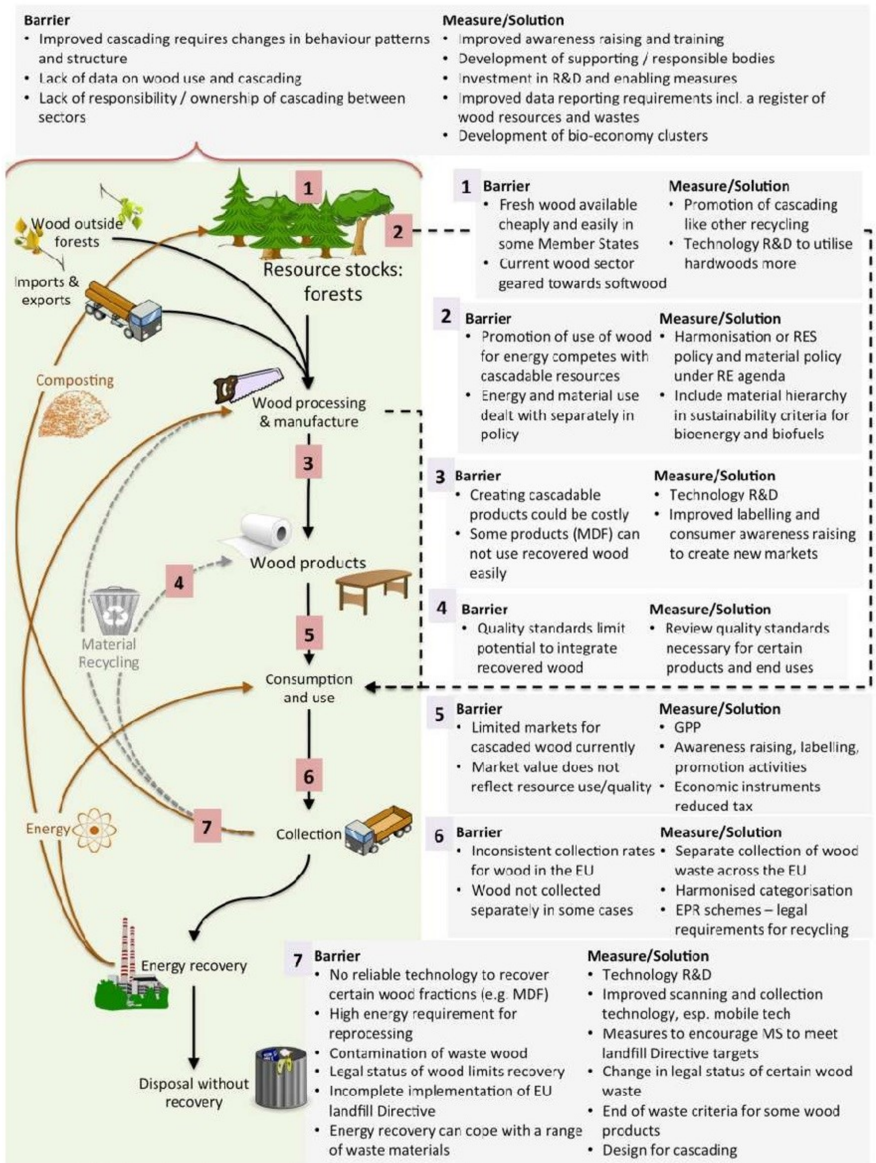


Figure 2.5.1. Barriers and solutions to cascading timber during the different stages in the material flow (Vis, Mantau and Allen, 2016).

The preferred order for wood utilization in end-of-life scenarios in EU Waste Framework Directive starts in order from the most preferred to the last option as follows: prevention, reuse, recycling, recovery, disposal (European Union, 2008). Ramage et al. (2016) has shortened these scenarios to three that are reuse, burning for energy and landfill of which the last one has been already banned in several European countries such as Sweden.

Naturally, the multi-stage cascade is the preferred alternative that is the underlying goal to be reached. Considering cascading wood from the perspective of large-span constructions, numerous actors are involved in the lifecycle of a construction starting from the suppliers of the wood material, to the decision makers and influencers of construction phase (architects, real estate developers and investors and construction companies), to the actual end-users and subsequent phases of maintenance and demolition (Antikainen et al., 2017).

In one study conducted for particleboard production in the region of North Karelia, the cascading of waste wood to produce particleboard made the production costs higher and used up more energy due to additional processing but this simultaneously could increase employment more than traditional particleboard production with virgin material (Suominen et al., 2017). Similar supporting results were discovered in a comparison of current cascading options, in which energy production were found to be most environmentally sustainable by a clear margin in all three metrics of climate change, acidification and eutrophication (Manninen, Judl and Myllymaa, 2015). This could have the implications that recycling wood for other than energy purposes may not be energy efficient, and the cascading practices should aim to enable the reuse of waste wood which would not require additional processing. Indeed, C&D waste timber material have been suggested to be recycled for composite materials, although the energy spent for processing have to be monitored so that the environmental effect remains net positive (Ramage et al., 2016). However, the benefits of cascading would seem to have more environmental benefits in other countries with less forest resources than Finland (Suominen et al., 2017).

A study from Germany notes that producers and customers seem be unwilling to invest in particleboards that utilize waste wood material (Höglmeier, Weber-Blaschke and Richter, 2013). However, it seems wood-based building materials have been increasingly designed to enable more convenient disassembly, and that precisely the design phase could provide opportunities to implement steps that allow removal of building elements intact (ibid). The same study suggested that one fourth of wood material could be reused and almost half recycled for particleboards, but only if the deconstruction phase would allow efficient recovery of these materials (ibid). A similar deduction came from a study in Finland that the role of primary design of a building for considering deconstruction phase could help to recover the deconstruction material (Sakaguchi, Takano and Hughes, 2016)

The challenges to obtain appropriate timber for construction elements already begins in the forest, where environmental conditions of the forest and climate affect the properties of the trees, which affect growth rate and wood density (Ramage et al., 2016). These two qualities then affect how sustainable and durable timber production is respectively. Other factors affecting the quality of timber are knots left by branches that may lead to concentrations of stress in timber, while spiral grain in trees determines how twisted the timber material will be once it is dried which both naturally affects the functionality of timber (ibid). The rotation for harvests of timber and planting new ones can vary around from 35 years to 70 years (ibid).

Some of the most common wood processing methods include impregnation, chemical modification and thermal modification which can alter the durability, stability and mechanical properties of timber (Ramage et al., 2016). When harvested wood is utilized as timber with long lifetime potential, harvested forests may actually sequester more carbon than if forest was left to grow indefinitely (ibid). Thermal modification of timber has been found to make timber more brittle in regards to bending and tensile strength ibid), which suggests that thermally modified timber may not be the best alternative for cascading timber, whereas acetylation might be more preferable treatment method as it can undergo same treatment as non-treated wood in their end-of-life. While impregnation of wood does not alter wood chemically, the impregnants may often be hazardous, which complicates their cascading (ibid). Winder and Bobar (2016) found that the regulations should discourage wood treatment, as they are preventing the increase of cascading timber practices. Coating on top of timber material has been considered a suitable option for timber in exterior usage and natural coating alternatives may be more environmentally friendly (Ramage et al., 2016). The best option would be to genetically enhance the type of trees that would be ideal for utilization without further treatments (ibid). Thus, genetically modified trees might help cascading practices pervade the industry in the future, as the material would better permit reuse and recycling.

Unfortunately, utilizing waste timber material directly to incineration as energy purposes seems to be considered as the most viable option from economic and technical perspective (Pirhonen et al., 2011). Therefore, the major objective should be to discover technical innovations and identify new practices that would enhance the prospects of reusing solid timber in some other function before releasing the material to energy usage.

2.6 Sustainable Construction, Buildings and Demolition

The concept of reusing material again in structural environment is perceived difficult process that would require changes among all the actors throughout the lifestages of the material (Hradil et al., 2014). Yet, a survey conducted by VTT Technical Research Centre of Finland Ltd has suggested that the overall attitudes from related actors and stakeholders towards reusing material for construction are generally positive (ibid). This would indicate that the barriers towards adopting cascading timber practices consist more of practical factors rather than attitudinal ones.

A database of both current buildings and already demolished buildings is stored in the records of the official Building and Dwelling Register (Hradil et al., 2014). These statistics reveal several interesting features of buildings and their demolition situation in Finland, such as that the demolition rate in Finland is among the highest in western Europe and the most common types of buildings demolished are non-residential both when measured in the amount of buildings (51%) and especially in the floor area (76%) based on time span between years 2000 and 2012 (ibid). Another interesting aspect from the report by Hradil et al. (2014) is that only few demolished buildings could be considered old, since four fifths of demolished buildings floor area had been constructed 60 years ago or earlier. However, a lifecycle of even a few decades causes assessments of new innovations and concepts to be problematic to conduct and approve as new best practices, which might be why only miniscule percentage of timber is still used in multi-story constructions (Antikainen et al., 2017).

Naturally, three quarters of buildings were demolished in city areas and the most common types of demolished buildings were "industrial buildings (1.7 Million m2, average area 1,260 m2, typically concrete), detached houses (1.4 Million m2, average area 90 m2, typically timber), public buildings (1.3 million m2, average area 1,160 m2, typically either concrete or timber), commercial and office buildings (1.2 million m2, average area 530 m2, typically concrete) and warehouses (1.1 million m2, average area 710 m2, typically concrete)" (Hradil et al., 2014:16). As non-residential buildings would seem to generate the biggest amount of waste, concentrating on these types of large-span buildings would be more efficient in all probability. The reason for almost half (47%) of the demolished buildings was due to a new construction in the area, whereas 44% of the demolitions were reported as "other reasons" and 9% was credited for poor condition of a building (ibid). This finding raises a question of whether or not parts of the demolition waste could be reutilized as building elements for a new building in the same land area and especially since construction of new buildings was found to exceed the amount of demolition in virtually all municipalities (ibid).

An examination of future prospects about demolition was conducted utilizing Delphi research method of surveying opinions of industry experts in Finland, which revealed that while stakeholders, who were not financially affected by the development of demolition, would prefer the level of C&D waste to decrease significantly, whereas the overall opinion of members within the industry would prefer the amount of C&D waste to either grow or remain the current amount (Hradil et al., 2014). Thus, demolition companies seem to have little incentive to encourage practices that would maintain wood material in reuse phase. Remarkably, almost no one expected the amount of generated waste to decrease, which would imply that actors have currently little incentive to reduce C&D waste. Despite original intentions, the participants of the study concentrated mostly on residential buildings which has left a gap to be explored around demolition of non-residential buildings and additionally, the participants did not make a distinction between reuse and recycling despite being prompted to give their opinions on the matter which could also indicate that the difference between the two concepts should be further elaborated with stakeholders. Yet, the respondents in unison considered that timber of all C&D waste should be reused by 2050 (Hradil et al., 2014), further justifying and supporting the rationale for the importance of the thesis research questions. However, behavioral dimension affecting the decision-making has rarely been examined, despite it having noticeable role for circularity in construction, since people's attitudes are often negative towards the propositions to live in houses built with reused material (Pomponi and Moncaster, 2017).

Multitude of barriers against reuse of both C&D waste and more specifically timber exist. Some general problems preventing the proliferation of reuse practices for most materials involve the demand or lack of it which could contribute to lack of awareness, scheduling of construction, the required properties of building materials and related norms (Hradil et al., 2014). The reuse of timber faces many obstacles of which its biodegradable nature was perceived to be the overall major obstacle despite traditional timber framing was seen as one of the more potential construction elements for reuse (ibid). Reusing materials complicates the design aspects of construction as well, since structural engineer requires the parameters for construction elements and it is uncertain whether or not reusable elements would be able match those (ibid). Antikainen et al. (2017) suggest that one of the barriers for timber construction in general would be lost talent and knowledge of the field, which highlights the difficulty of implementing reuse of timber in constructions.

As part of the research by Hradil et al. (2014), 35 architecture students helped the research team to distinguish ten general design principles to reuse timber material. These design principles entailed essential insight to better utilize for construction, such as designing smaller spatial spaces and structures, since shortness of reusable material is a genuine problem. Also, designing asymmetrical components for the building can help when the reusable material varies in size and compartmentalizing elements such as studs based on their function, defining the dimensions of component areas instead of the material, using more efficient structure forms, repurposing and combining materials such as beams to columns based on what fits the purpose of available materials the best and allowing the "patina" of the reused elements to show to users. The common themes beneath the most of the principles seem to be modularized approach to building and having flexible plans that accommodate to the available material.

The less processed timber is, the more environmentally friendly and energy-efficient alternative it becomes in comparison to steel and concrete as a building material, which is why researchers have started to explore methods to utilize green timber that has not been industrially dried (Ramage et al., 2016). The potential and challenges for cascading green timber seems to be still unexplored area, but could have great potential from environmental perspective.

Deconstruction should always be used over demolition to prevent damaging C&D timber material and reuse be preferred over recycling solid timber by processing it to particle or fiberboard (Hradil et al., 2014). However, grading adjusted for reusing solid timber has not yet been developed, as normal grading does not take into account multiple possible failures that could be present in C&D timber (ibid). Regardless, the level of damage in the material should be assessed to avoid faults such as large holes, notches, shakes, splits, cracks, checks, shape distortions and biotic damage, although some of these can be repaired with sawing to reduce cross-section or treatments (ibid). Additional things affecting reuse of timbers are the used connectors to materials, as they cause different kinds of damage and their disassembly should be carried out in the least destructive way and the documentation of original grading certification should be ascertained if possible or else to document the location and original purpose of the timber material to be reused (ibid). For example, glue tends to have higher climate impact than traditional connectors of wood, such as pegged mortise and tenon connectors (Ramage et al., 2016).

Calculating the economic benefits of DfD is complicated due to the long and uncertain lengths of building lifecycles (Hradil et al., 2014). The complexity is increased by the difficulty of assessing the residual value of the reusable material and the cost of deconstruction in comparison to demolition (ibid). Lifecycle analysis comparing climate change impact of timber and concrete in high-rise buildings from three to 21 floors revealed that when reuse and recycling is included in the calculations, the timber causes lower climate change impact regardless of the amount of floors (Skullestad, Bohne and Lohne, 2016). Thus, timber as a construction element even for large-span and taller buildings seems to be a feasible alternative from environmental perspective. However, timber as a building material is rarely sufficient, as buildings must adhere to address certain structural challenges, such as floor vibration and thermal performance that timber alone may not be able to fulfill (Ramage et al., 2016). Additionally, while light timber frame has been found to be feasible to bear less load for floors than CLT-elements, but the volume of required timber material may be even less than half of CLT-equivalents (ibid).

Pomponi and Moncaster (2017) have proposed to have a holistic consideration that views the collaboration of economic, environmental, technological, governmental, societal and behavioral elements for the built environment. The successful implementation of these elements would necessitate transdisciplinary cooperation from several fields of expertise and research. Thus, ecosystem view on construction industry might help to identify how to execute such collaboration of different yet supporting disciplines.

2.7 Practices in other countries

Reusing timber from old buildings has become more prevalent in the United States, where a niche market has been found for over 100 years old redwood timber as luxury interior or furniture (Pirhonen et al., 2011). As older building frames often consist of large-dimensional timber, deconstruction of these parts has been profitable for recycling companies, and the estimates of reuse and recycling yield vary greatly from 50% to higher in the United States (ibid).

As placing still usable C&D waste to landfill is banned in Netherlands, the amount of recycled and reused waste is about 90&, although portion of the waste is likely imported to other countries (Pirhonen et al., 2011). In fact, C&D timber waste has negligible market in Netherlands, which is why most of it is imported still, which might change with the new circular economy goals of the European Union (ibid).

Germany has instantiated cascading timber practices with several efforts. For example, an organization has approached the issue from cluster perspective, which considers the actors also outside industry boundaries and instead frames it geographically in the state of Bavaria, where they have emphasized "material efficiency, life cycle analysis, product certification" and "industry actors previously not considered to be part of wood products sector (Winder and Bobar, 2016:4). Awareness and updating technology such as Building Information Modelling (BIM) has been seen as a requirement to better support cascading timber (ibid). Demolition actors have already adopted an auditing tool to compare the costs of demolition in comparison to deconstruction by comparing the value of materials (Pirhonen et al., 2011). Actors in construction sector have identified that the underlying problem preventing cascading timber stems from consumer attitudes that prefer economical alternatives over sustainable and thus more expensive buildings (Winder and Bobar, 2016).

Great-Britain has adopted social firms that are non-profit organizations with the agenda to increase employment, to collect valuable C&D waste material from the constantly generating waste stream (Pirhonen et al., 2011). These social firms generate revenue from companies for collection and then compiling timber material according to quality categorization and sell the material either for direct use or for reprocessing (ibid). However, only one tenth of the waste timber is categorized to first class, whereas the rest are categorized in second and third class as the material is too small or short (ibid).

2.8 Policies & Regulations

While regulators lack tangible role in the business ecosystem, their influence and decisions determine the economic prospects of different waste utilization opportunities based on the established policy and regulatory frameworks (Peltola et al., 2016). One example supporting this view is the general opinion of industry experts that regulations have clearer impact to utilizing timber for constructions than expressed consumer preferences (Toppinen et al., 2016). A survey of actors and stakeholders in Finland revealed that the most substantial barriers to reuse structural elements were the legislative constraints and unestablished standardization (Hradil et al., 2014). Even more concerning, signs of lack of inclination to develop policies that would encourage reuse and circular practices have been apparent in the EU (Pomponi and Moncaster, 2017). Furthermore, product codes and standards seem to be the barrier preventing utilization of timber for higher multi-story buildings rather than physical qualities of the timber (Ramage et al., 2016). Thus, this section aims to explore and identify the regulatory aspects and possible policies to advance cascading timber.

The suggested phenomenon curbing the development of a more sustainable bioeconomy also seems to be the divide on thinking and future targets of policymakers, which ideology seems to rely on maintaining same capital growth with more renewable and sustainable structure that deviates from the visions of other influential stakeholders, such as scientists, whose views and position of the debate are much more scattered (Hausknost et al., 2017). Thus, open discussion and information sharing among the various actors in the field could help to align the sustainable practices to a more uniform direction, which could enable cascading wood practices to gain more support.

European Union has set an ambitious target to have 70% of C&D waste material reused or recycled in their Waste Framework Directive by 2020 (European Union, 2008). This goal has been supported by the recent publication of EU Construction & Demolition Waste Management Protocol that aims to promote the reuse of C&D waste by identifying improvement measures and building trust to C&D recycled materials with legislation and quality management (European Commission, 2016b). However, one of the contradictory aspects to waste material reuse arise from the renewable energy targets of EU to have 20% of overall energy consumption to be renewable energy without regarding the reuse and cascading principles (Birdlife Europe and the European Environmental Bureau, 2015), which might encourage the utilization of virgin biomass for energy use instead of waste material.

Waste Framework Directive already set prioritizations for waste treatment, where the priority stages abide by the principles of waste hierarchy and circular economy that is even more binding in Finnish waste legislation (Raitanen et al., 2017). However, exceptions from the hierarchy are allowed if other alternative methods would provide lower environmental impact and the interpretations of national legislators allow for various classifications that could provide optimal utilization of waste (ibid). Thus, comparison of different EU countries could have quite different examples of waste lifecycles for timber. Furthermore, Finland has decreed a ban on landfilling waste material that contains more than 10% of biodegradable material, but construction and demolition waste was granted an extension until the year 2020 to have maximum of 15% in material going to landfill (Pfister, 2013). The change towards more resource efficient practices seems to be still under process.

European Commission has put forth four legislative proposals on waste policy in 2015, along with their new circular economy package (Bourguignon, 2016). These proposals include insights, such as setting a monitoring for compliance with targets, simplifying classification from by-product and end-of-waste status back to usage and setting new targets for reuse and recycling (ibid). Numerous measures to promote circular economy by European Union have also been identified, which consist of communication, financing instruments, guidance and best practices, implementation and enforcement, indicators, legislative measures and support (Bourguignon, 2016:6). One of these measures is the decision not to define energy use of waste material as recycling any longer (European

Union, 2008). Since European Union seems to have acknowledged the urgency of circular economy, the practices and requirements may change rapidly in the coming years. The most recent development from the European Union is Level(s), a reporting framework that utilizes numerous metrics to promote sustainable buildings (Dodd et al., 2017).

One underlying problem in policymaking is the current prevalent mind-set where companies perceive sustainable practices only as a necessity as required by policymaker and there is a need for paradigm shift towards more proactive attitude and behavior to accelerate the change, as such actions have a tendency to also benefit the proactive companies (Robèrt and Broman, 2016). Nonetheless, the complexity of wood-based bioeconomy sets many challenges for working and supporting policies, as large-scale market steering initiatives have a high risk for errors, but policy support towards technology niches seems to be easier to execute (Purkus et al., 2016).

Hradil et al. (2014) suggest policymakers to implement regulations to promote material efficiency and take the demolition waste into account in lifecycle design which would incentivize the design for deconstruction already in the design phase. At the moment, estimated calculation of reusable C&D waste material is not required, but instead only inventory of quantities and qualities of C&D waste is required by Finnish Land Use and Building Act (ibid). Following the EU Framework Directive, Finland also enacted new Waste Act that strictly conforms to former, and maintained the same criteria of by-products that constrains treatment of waste to specific terms (Levänen, 2015). The purpose of the by-product criteria seems to be to improve the communication between industry actors and authorities, yet the criteria does not help in value creation of new innovations, but instead seems more applicable for harnessing current knowledge (ibid). As such, there seems to be plenty of improvement in policies and regulations.

Zaccai (2012) identifies five policy instruments that could be employed to promote sustainable development. These policy instruments are norms such as ISO standards, market-based instruments such as carbon market, voluntary instruments such as CSR reports, collaborative actions such as partnerships with NGOs and companies and finally, information instruments that considers how the message of sustainable development is conveyed to the society and actors. It would seem that the all of these policy instruments involve the actors in the industries themselves even more nowadays, and as they can have influence on all the instruments, which is probably why norms may not be as efficient as other guiding measures.

Figure 56: Intervention points of EU measures related to cascading use

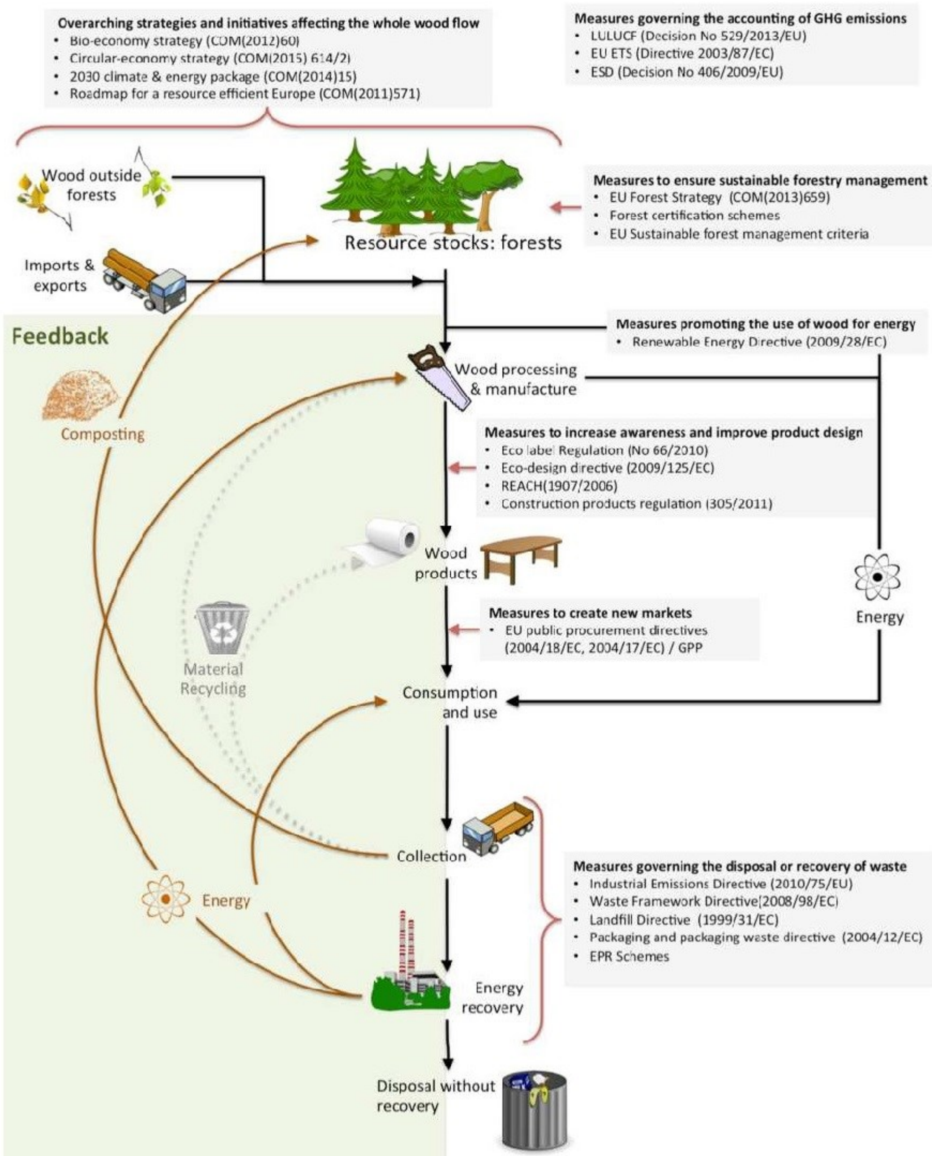


Figure 2.8.1. The effects of EU-level policies to cascading timber (Vis, Mantau and Allen, 2016).

Figure 2.8.1. by Vis, Mantau and Allen (2016) shows the various policies that may have direct impact on cascading timber. The illustration portrays the policies based on their identified categories which are "overarching strategies and initiatives; information measures, regulation, market based instruments, public and private investment and voluntary approaches" (Vis, Mantau and Allen, 2016, p.123) Thus, all of these regulations

bind the legislation and policymakers in Finland as well to adhere to the same requirements as the rest of the member states.

2.9 Certifications

One developed standardization approach to measure and inform the environmental impacts of products in a uniform way across European Union is called Environmental Product Declaration (EPD) that combines Life Cycle Assessment with Product Category Rules (PCR) of which EN 15804 defines what parameters and stages of lifecycle to be included in the overall EPD (Hradil et al., 2014; Ramage et al., 2016). EN 15804 presents its information in LCA like format of stages where however the first stages of lifecycle (production phase) of products or buildings are required by EPD (Hradil et al., 2014), which demonstrates the inefficacy of the current PCR to gauge the sustainability of entire building as the stage of reuse and recycling still lacks proper definition. In fact, the types of EPD scenarios for information modules do not still have cradle-to-cradle option, which is also most likely why the information module for reuse and recycling is still optional for all types (Building Research Establishment, 2016). The reuse and recycling module, labeled as module D, is considered to be outside the boundaries of a system as a scenario-based that fails to include temporal issues such as production systems changing over decades from the original purpose of a reusable material (ibid).

EPDs of construction element products are required to be eligible for labels and ratings such as BREEAM, DGNB, HQE and LEED that are used to certify sustainable buildings (Hradil et al., 2014). The following section will briefly examine these four certification systems, since PromisE, the assessment tool for environmental certification is not in use anymore (Green Building Council Finland, no date).

2.9.1 CE marking

Construction elements are required to have CE marking in accordance to Construction Products Regulation (Hradil et al., 2014). The CE marking has become or is about to become practically all timber construction material and they adhere to harmonized European Standards, which permits exporting and importing of timber within European Union (Puuinfo, 2016). However, the requirement of CE marking might prove problematic for reuse of C&D waste, since the origin of material might be difficult to ascertain in some circumstances. This is why some member states of EU have already advocated for CE marking not to apply to reusable materials (Hradil et al., 2014).

At the moment, solid construction timber to be used for buildings needs to be strength graded according to standards of EN 14081 (Ramage et al., 2016), which means that reused timber would have to undergo the same standardization procedure. In Finland, the timber material is certified as SFS-EN standardization by Finnish Standards Association that follows the norms of the harmonized European Standards (Ympäristöministeriö, 2013). CE marking might be one of the biggest barriers to prevent the proliferation of cascading solid timber material.

2.9.2 BREEAM

BREEAM certification provides sustainability assessments for buildings in every stage of lifecycle conducted by government authorized certification bodies that are allowed to pass BREEAM ratings (BREEAM, 2018). The certification scheme originates from UK, where it is the main certification methodology (Inbuilt Ltd, 2010).

2.9.3 LEED

LEED was established in the United States by Green Building Council (Inbuilt Ltd, 2010). Apparently LEED rating has become widespread already in several states, so that even planning of residential areas are based on LEED-standardization (Pirhonen et al., 2011). LEED certification is supposedly more transparent than BREEAM, but its rating system is tied to US dollar in some metrics, which might create confusion in other countries and affect the rating based on the currency exchange rate (ibid).

Common element for both LEED and BREEAM is that they appoint credits for using timber in constructions, as well as for locality of the construction element and for reusing or recycling materials (Antikainen et al., 2017). Thus, cascading solid timber would yield better certification rating both in construction and demolition phase of buildings. However, LEED seems to have more lenience for the procedures and design of building to achieve desired outcome compared to BREEAM that would seem to have their metrics interconnected to specific approach, which would limit the designers' possibilities to reach the set goals in creative ways (Inbuilt Ltd, 2010). This could be due to the fact that BREEAM criteria is considered to be more based on scientific findings, whereas LEED has faced accusations of having their criteria attuned according to construction manufacturers interests (ibid). Finland had 94 LEED certified and 35 BREEAM certified buildings by November 2015 (Green Building Council Finland, 2017).

2.9.4 DGNB & HQE

Additional certification programs in European Union are HQE (High Environmental Quality) that likewise endorses sustainable buildings (European Commission, 2016b) and DGNB System from Germany which claims to be unique in its flexibility to align the criteria and certification to any type of building or regulations of different countries (DGNB, 2018).

2.10 Conceptual Framework

The conceptual framework for the business ecosystem related to cascading solid timber is inferred and constructed from the existing body of research, business ecosystem theory in addition to author's previous experiential knowledge (Maxwell, 2013). Referring back to RQ1, the conceptual framework aims to illustrate a simplified model of actors of the existing business ecosystem in relation to the supply chain lifecycle of the timber material and how to address the circular economy approach to cascade solid timber.

As identified in the business ecosystem and sustainable construction sections, the relevant actors start from the forest owners. For example, Metsähallitus is a major provider of raw timber materials from nearly 40% of the commercial forest land area in Finland (Metsähallitus, 2015). The timber material is then processed at timber manufacturers and building element manufacturers to products conforming to the requirements of the construction industry. Then, the timber products are utilized by construction companies based on the design and requirements from building owners and architects for buildings. Finally, End-of-Life status for timber as C&D waste is often treated as energy or imported to landfills, but these scenarios are left to minor attention, as the main concern is for the reuse and then recycling of the waste material. This final phase in linear lifecycle is handled by demolition and waste management companies.

Sectoral boundaries are recognized as having a siloing effect on the actors which is visualized with vertical dashed lines in the business ecosystem. The business ecosystem is considered to contain multitude of value networks between actors which possesses possibilities to exchange value of products and services, money, knowledge and intangible benefits such as good will (Allee, 2000). Exploring different ways to reconfigure these value networks for better optimization could generate answers to RQ3 and RQ4.

While sectoral boundaries restrain actors from more effective collaboration, policies have established their own boundary and restrictions to the ecosystem that bind actors' actions to certain tracks. It is worth noting that organizations from other industries and other non-governmental organizations may not be as confined with set best practices as the actors within the ecosystem. The same is perceived to apply to academic stakeholders and consultants.

Barriers that consist of governmental, technological and economic factors are considered to prevent cascading practices of solid timber. These barriers prevent the C&D timber waste material to return to timber material lifecycle for reprocessing or direct usage. Examination of these barriers is directly related to RQ2. These barrier dimensions are derived from the six dimensions of the circular economy framework by Pomponi and Moncaster (2017). The environmental dimension is exceedingly important, but is left outside the scope, since prevention, reusing and recycling has been indicated to be environmentally preferable over energy use or landfilling. Societal and behavioral dimensions are also considered, but they are already embedded in the concept of business ecosystems.

Based on these insights, the conceptual framework was created as seen in fig. 2.10.1 This conceptual framework will be utilized for sense-making to derive essential question from the actors in the business ecosystem during the primary research.

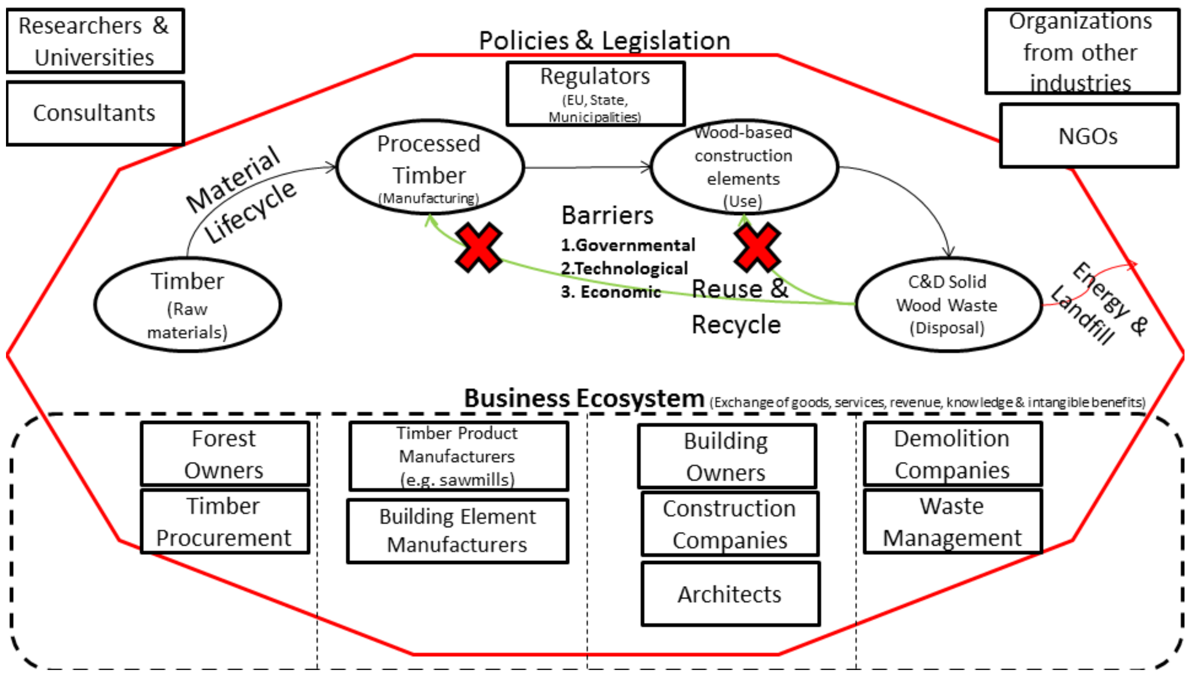


Figure 2.10.1 Conceptual Framework of Business Ecosystem around the lifecycle of C&D timber.

3 Research Design for the Qualitative Interviews

The following section details the selected approach and reasons for the primary research. The selection of research sample is also explained and justified. The limitations and validity of the primary research are also discussed and clarified before starting the analysis of research results.

3.1 Methods

To relate back to the research questions of exploring the barriers, actors and potential solutions for cascading C&D timber, the best source of information would most likely be the actors within the business ecosystem. The applied ontological and epistemological approaches in regards for the research philosophy, that frames the methodology design in this research, follows subjectivism in the form of social constructionism and interpretivism (Eriksson and Kovalainen, 2011). This is due to the fact the methodology involves assessing the viewpoints of various actors in business ecosystems through discourses that are likely to maintain different views and perspectives from other actors and even individuals operating in similar roles. It is the belief of the author that all information is subjective by its nature.

The method of data collection relies more on the deductive inquiry, whereas the literature review and the conceptual framework are built on inductive reasoning (Eriksson and Kovalainen, 2011). Also, the design of the research could be perceived mostly as cross-sectional, but also pertain longitudinal aspects, since the business ecosystem actors can expose opinions, ideas and information that are reflected to the current moment and to the future.

The selected most appropriate method for the primary research is to conduct face-to-face semi-structured interviews with constructionist approach (Eriksson and Kovalainen, 2011). This approach allows for more informal and open discussion between the interviewer and interviewee that helps to unearth further details, which more rigid structured interviews or questionnaires would fail to retrieve. The nature of interviewing is inherently animated interaction, which naturally involves bias which should be considered from the perspective of how it generates data instead of only seeing it as contaminating data, but to consider the context of narratives through questions such as "how, where, when and by whom" (Silverman, 2011, p. 163)

The interview questions are applied as probes to elicit value from the selected sample. In that respect, the research questions are employed to describe what the author seeks to understand, whereas the interview questions are utilized as means to evoke and capture the useful data to gain understanding of the topic (Maxwell, 2013). As such, the strategy as well as the questions for the interview are subject to change over revisions after each interview, to better define the questions to match the expertise and interest of the interviewees.

The questions explore the roles and current practices of the actors and aim to generate slightly more hypothetical insights into future of how the actors imagine the industries to operate and how cascading timber could be integrated to these practices. Aiming to answer all the research questions and develop the conceptual framework further, the questions will also inquire about the view on barriers, what impact they have and how those could be resolved. The issue of cascading C&D timber is approached from economic, technological and governmental dimensions, as identified in the conceptual framework. Stakeholders outside the business ecosystem might be able to provide input from other sectors that could be implemented to the ecosystem in question. The interview question template is attached in the appendix.

While the original aim of the interviews was to ask the same questions from all the interviewees, the set of questions was not rigorously followed in reality. The reason for this was to maintain the natural flow of the discussion between an interviewee and the interviewer. Often the answer to one question already contained answer to another question, so asking the question would have been redundant. This would have also only served to frustrate the interviewee. Likewise, some questions were omitted depending on the interviewee and their expertise, since the interviewees represented a varied pool of experts from different fields and disciplines, which made it evident that they possessed knowledge in certain area, whereas they had little to share in others. Thus, often the decision was made to concentrate on questions where answers proved more productive to take full advantage of the duration that the interviews were agreed to last.

The data analysis is conducted based on gathered memos and transcripts of the audio-recorded interviews. The purpose of analysis is to generate valuable knowledge that contributes to the research questions and conceptual framework. As such, instead of only applying the traditional computer-assisted qualitative data analysis to code and categorize the content of interviews, the analysis phase will also use connecting strategies to develop interesting relations between identified categories of discussions (Maxwell, 2013). This approach is utilized to construct more systemic view of the topic that enables to identify various interdependencies of the actors and the relations of factors that would help to generate a vision of how the business ecosystem should be developed, instead of merely categorizing mentioned factors, since the previous literature seems to have provided encompassing analysis of existing factors and barriers already. As such, this analysis could provide better insights and knowledge than quantitative surveys or resorting to only analysis of reports.

3.2 Research Sample

The sampling method of the semi-structured interviews is based on both backyard research and also on convenience sampling (Eriksson and Kovalainen, 2011). This is due to relevant actors that the author has already met previously or aware of through contacts and received further interviewees gained by networking with the previous interviewees. As such, the research sampling has been a type of networking process. However, purposeful selection is applied as well to select from potential interviewees those that are most likely to provide value and are able to provide relevant input (Maxwell, 2013). Also, all of the interviews are conducted within Finland to reflect the business ecosystem on a national level.

The sample thus includes actors from the sectors and stakeholder parties identified in the literature review and conceptual framework to ensure the heterogeneity of the research sample and identify differences between the actors (Maxwell, 2013). In order to gain the interviewees informed consent, the background of the research is explained in detail prior to interviews (Eriksson and Kovalainen, 2011). The confidentiality and anonymity are given to interviewees in order to establish trust and ensure the willingness of interviewees to share their real opinions (ibid). Therefore, all the interviewees are anonymized throughout this paper and as their opinions and insights are discussed, the interviewees are referred according to descriptive codes as classified in the list in figure 3.2.1.

All in all, 21 interviews were conducted to obtain an encompassing overview of the potential ecosystem and the actors within. Thus, the interviewees consist of various experts from all the identified sectors mentioned in the conceptual framework and also a few related consultants and specialists from organizations and public sector. The table 3.2.1. below identifies all the interviewees. As actors further in the value chain were perceived to be more relevant to the thesis topic, the amount of interviews was greater in the end than in previous sectors. The decision to skew the sample towards the actors involved in end of timber lifecycle was made early in the qualitative data collection phase.

Table 3.2.1. Anonymized list of the final participant sample categorized to five differentiated units based on the conceptual framework generated based on the literature review.

Code	Interviewees	Description of organization
Forestry:		
F1	Sustainable Development Manager	An organization that manages and trades significant portion of forests in Finland.
Manufacturers:		
M1	Specialist	A lobbying organization for wood construction and wood product industry which deals with promotion, standardization and environmental matters.
M2	Environmental Specialist	A lobbying organization for forest industries.
M3	Vice President of R&D Unit	A major company in Finland dealing with diverse product portfolio of wood-based products.
Construction sector:		
C1	Environmental Manager	A lobbying organization for construction industry.
C2	Project Engineer	A housing investment company that also has a unit for new building development.
C3	General Engineer	A construction company specialized in wooden buildings.
C4	Architect	An architect office specialized in wooden building projects.
C5	Architect	An architect office working on all kind of projects from interior design to city planning.
Environmental & waste management and demolition:		
E1	Communications Manager and Business Controller	An environmental services company involved in both demolition and recycling.
E2	Operations Manager	An organization functioning in waste management of households and small companies.

E3	Environmental Manager	An environmental services company that also recycles wood waste.
E4	Service Coordinator and Process Engineer	An environmental services company involved in waste transporting and management.
E5	Specialist	A lobbying organization for environmental services industry.
Other experts, consultants and policymakers:		
O1	Chief Executive Officer	An organization specialized in cleantech.
O2	Professor, specialized in forest industry	A university in Finland.
O3	Research scientist	A research and technology organization that also has a research unit for circular economy
O4	Consultant	An organization promoting sustainable construction. The interviewee also works in a circular economy consulting company.
O5	Senior Expert	An organization providing material efficiency and sustainability consultancy.
O6	Specialist	A ministry in Finland.
O7	Team manager	A city planning and zoning office in one of the major cities in Finland.

Majority of the interviews varied between 45 to 60 minutes in length. The shortest interview was about 32 as minutes long, whereas the longest interview lasted a little over 87 minutes. Nearly all of the interviews were conducted within the premises of interviewees' organizations, excluding couple exceptions which took place in public spaces. The location for the interviews and the organizations involved were in The Helsinki Metropolitan Area, again with the exception of one interview carried out in Tampere region. All the interviews were carried out within two months in January and February of the year 2018. The language used in the interviews was usually Finnish, as it was the native language of both the interviewer and interviewees. This excludes couple interviews in which English was the language used to carry out the interviews. Any extracts of interview transcripts highlighted in the findings have been translated to English, if they have not originally been in that language.

3.3 Limitations & Validity

Naturally, several limitations are imposed to the primary research. First is the time constraint to conduct the primary research that restricts the amount of interviewees to be narrowed to one or two stakeholders per identified roles in the business ecosystem. Another type of time constraint follows from the practicalities of requesting and appointing interviews with the interviewees, since requiring them to allocate more than one hour of their time for the interview would prevent or cause hesitations due to other responsibilities. Thus, interviews can only delve in-depth for a few central topics to stay within time limit.

The validity of the data and findings is subject to several factors, although some researchers reject the concept of validity as invalid for qualitative research (Maxwell, 2013). One of the concerns for the validity of the data and findings is the subjective nature of the findings, since only a small group of experts from business ecosystem are interviewed. The effect of this can lead to generalization of findings (ibid). Some interviewees views might diverge entirely from the rest of the actors in the sector and possibly even inside the organization.

Many of the validity threats concern around the authors ability to identify the threats and neutralize them early on, such as the researcher bias and reactivity (Maxwell, 2013). A researcher may have tendency to concentrate or prefer the data that complies with the established ideas and theories of the researcher. The strategy to negate the effects of validity threats due to the nature of the research would be to scrutinize discrepant statements and find contradictory data and negative cases to assess the validity of findings and either redactions or inform about any perceived discrepancy along with the finding (ibid).

4 Analysis of the Ecosystem: Insights from Interviews

The structure of results resembles the structure of literature review. The reason for this is in part that the emerged themes from the interviews seemed to correspond to the explored subjects of previously explored academic discourse and arranging these themes in the same order made sense to preserve the clarity of explored ideas. Another reason for the seemingly preserved structure may also stem from the fact that the initial interview questions were synthesized based on the insights derived from the literature review. The order of themes also aims to progress from more general plane of discussion from which the specificity is narrowed down to present the findings for more distinct elements of cascading timber. Since the interviews and consequently produced findings could be seen as co-created with the interpretations of the interviewer and the shared knowledge and information of the interviewee, the author is taking the liberty to address oneself in first person in this section of the text to accentuate the subjectivistic and interpretivistic nature of the findings.

In total, 83 codes were identified and used to categorize the interview transcripts. Nine categories emerged out of the codes as their own themes, which serve as the frames to discuss the findings of the different actors. First, the role of actors and the business ecosystem in general is overviewed. Construction and waste management sectors are both delved further, before highlighting the results related to design and planning. Next, the findings present the insights related directly to cascading of timber, which is then followed with a closer look to economic, technical and regulatory aspects of the topic. Finally, interviewees' thoughts on potential solutions and the future are shared. Some of the most topical issues are condensed to key insights on tables in each section that also identify their dimensional attributes based on the circular economy framework by Pomponi and Moncaster (2017).

4.1 Actors & Business Ecosystem

Discussions with interviewees related directly to the business ecosystem surfaced little insights or opinions at first. The concept of a business ecosystem seemed somewhat obscure for several of the interviewees despite the term and its context being defined in the beginning of all the interview sessions, which I then decided to de-emphasize in the later interviews and instead aimed to induce analogous information with discussions about industrial collaboration and power structures. Consequently, the information distilled from these discussions was also used to delineate the findings that could contribute to understanding the nature of potential business ecosystem.

"Difficult to say what value chain wouldn't be important. It requires the formation of a new extensive value chain. The perception that it reaches to early stages, meaning already the design of a building, is quite important. You can't start it from demolition project perspective." - O1 citation

O1 citation presents a more extreme opinion from O1 about the direction that the overall business ecosystem should transform into something new. However, it is noticeable that even here the business ecosystem thinking does not extend across the sectoral boundaries from the construction sector to view the earlier sectors of forestry, timber procurement and manufacturing. In fact, C1 stated that the value chain already within the construction sector alone is considerably long. Similarly, the contemplations of the business ecosystem from F1 corroborate the claim by concentrating only on the timber purchase and associated saw mills. Hence, I will explore some reasons below to why the seemingly connected and subsequent sectors are segregated from each other.

Traditionality of the two sectors is contributed as one of the factors that prevent the proper emergence of a business ecosystem, which is why O2 considered "actor network" to be a more appropriate term to describe these sectors. However, O2 later conceded that these could be perceived as business ecosystems within these separate sectors. First one would be formed by primary production, processing and manufacturing of timber components. Second is the construction sector that included architects, clients, investors and end-users. Then, circular economy and recycling companies form the third entity with its own conventions.

"So yes, I see that co-operation is strong in practice, in purchase and procurement of wood and we are strongly connected to wood purchasers. But it could be said that in ivory tower, at the top level, of course co-operation is immensely important, when co-operation is done from sustainability point of view or agreeing on criteria on how to operate even better."
- M2 citation on the level of collaboration in forest industry.

The extract above illustrates the high functionality of forest industries. The same sentiments of tighter collaboration within the forest industry seem to be shared by O2 and F1. Interviewee O2 argues that: *"wood products industry has permanent relationships, but there is still quite strong competition, then the construction industry is branded by its nature of subcontracting."* The fragmented nature of the construction sector would appear to extend to recycling and waste management companies according to E2. Therefore, the most apparent schism has formed between the wood product industry and the construction sector that only interact through direct business transactions of wood products.

Few of the interviewees directly mentioned the issue of silos, while it tended to be an underlying theme in some of the discussions. C2 perceived that the silos could be related to complexity of each major construction project, which prevents the development of effective streamlined processes that have benefited the wood product industry. Likewise, the ambiguity of responsibilities in the waste management sector divides the actors. On the other hand, O2 thinks that the wood product industry is itself quite self-contained, as they are unconcerned about the final destination for their products or how to seek gains for the future. Thus, both the sectors and the organizations within sectors are experiencing the silo effect.

"Well, a lot of new actors have popped up now. This kind of smaller and more agile construction companies, so would they bring any kind of solution to this." C2 citation

While the traditional way of doing things may determine much of the constructs within the sectors and organizations, none of them are still immune to change. M1 maintains that despite the apparent silos, the actors have already started to fill gaps in their wood product offerings that consider the seemingly rising trend of wood construction. This then seems to be a related response to the rise of new type of actors in the construction sector as described in the C2 citation. Despite silos, the sectors still react to the opportunities in the market.

But which actors are controlling and influencing these sectors or their sector-specific business ecosystems? No precise consensus emerged from the interviewees since the responses had a tendency to be dependent on the role of the interviewees. For example, an architect point of view saw that the developers especially in Finland usually have the last word in decision-making, whereas the developers perceive the legislation and town planning to have crucial role in the end-results of construction projects.

The decentralization of power and influence reveals that no actor or entity has attained encompassing dominance over the others. For instance, those who have influence in the actualization of circular economy principles may be different from those who dictate the designs and materials of buildings. This interconnectivity and decentralization of influence could support the business ecosystem theorem, as the distribution of power seems to be divided and shared by multiple actors.

"So, this chain is long and the responsibilities and ownership in a way gets cut along the road" - O5 citation on the problematics of roles and relationship to increase circular economy.

As the O5 citation establishes, the business ecosystem for cascading C&D waste wood poses itself as a complex system that is affected by many stages and the actors within.

These dynamics of actors will be explored in further detail in the following subsections to better comprehend the nature of the business ecosystems.

Table 4.1.1. Summary of the most relevant findings in regards to the actors and business ecosystem.

Dimension	Actors & Business Ecosystem - Insights
S	Low level of collaboration between the three sectors in the business ecosystem.
S	Tight relationships between actors in the forest industry.
S	New actors emerging in both the forest and construction industries.
S	Decentralization of power and knowledge in between the long value chain of timber lifecycle.
T=Technological; M=Market/Economic; G=Governmental/Legislations; E=Environmental; B=Behavioral; S= Societal	

4.2 Construction Sector

4.2.1 Circumstances of the Construction Sector

As the business ecosystem is examined from the perspective of timber lifecycle and its end-of-life as C&D waste wood, the construction sector is pertained to the ecosystem as a central node to the continuity. Communication of building information in the building lifecycle seems to usually get cut off early on, as the actors responsible for the construction phase are usually different than the actors responsible for the maintenance of a building. Additionally, interviewee C2 elaborates that enormous amount of information is generated in during construction, which means that the maintenance organization has to start over to catalog all the materials and information. Sometimes, the communication in general is nonexistent even between units of the same organization, which interviewee O1 had observed in the internal communication of major actor's construction and demolition units.

An important aspect for the construction sector and the related built environment is the scale of time. As I inquired the interviewees on their views for the future in next five years, especially those directly involved in the construction sector were convinced that changes in such a short time span would be negligible. I corrected my error in later interviews by switching the five years to ten years. Obviously, the inertia against renewal within the construction sector is inherently embedded due to the long lifecycle of buildings. In other words, the renewal rate of constructed environment is extremely low, about one percentage per year as mentioned by the interviewee C1.

"Construction is nevertheless advanced in here. It is efficient and there is know-how, so one reason might be honed down processes. Those certain changes related to recycling and directives might be more difficult to execute. Turning around one big ship is more difficult than turning a small boat." - O2 citation.

O2 citation above helps to illustrate the circumstances of the construction sector in Finland with an analogy describing the difficulty to enact change in bigger organizations and related formed practices around their activities. The construction sector in Finland seems to be centered on a few major players that compete for the large-span construction projects. In that sense, the wood product industry and the construction sector seem to share parallels with each other, as both have a few dominant industry leaders and several smaller actors.

Thus, the processes applied in the construction sector have already established entrenched position that might be difficult to convert in order to utilize entirely new methods, for example such processes that would support cascading of timber more than the current ones. Moreover, switching to new processes without proper validation, such as successful tests and experiments, would be seen as irresponsible for the risk-averse sector.

One solution could be to benchmark and adopt processes and policies from other countries that have shown success in implementing circular economy ideology to their systems. However, the common practices in construction sites differ on a country-basis. One major reason driving these differences was discussed with interviewee M3, who shared a notion that the role of cultural constructs has a major impact on the construction sector. For instance, certain alpine countries in Central Europe such as Austria have massive timber buildings ingrained as part of their culture, which in turn has allowed new timber products such as cross laminated timber elements to be more readily supported in the market, whereas market areas such as the United States and the United Kingdom have inclined more towards light-frame construction. Likewise, the construction materials and, consequently, processes have become predisposed towards light-frame construction and concrete here in Finland. Naturally, these countries have developed a strong industry to back their preferred construction methods, which then have tied the market to their own heritage which prevents diversity of construction sector and buildings.

Differences between countries may also extend to the role of actors. While architects may be considered to have major influence in the end-result of buildings, architect C5 considered the role of architect in Finland often to be just an illustrator of spreadsheets and that these plans are often not adhered to as rigorously as country of comparison that was Switzerland, where according to the interviewee an architect's role usually extends also to that of a construction consultant. Similarly, interviewee O2 shared the sentiment of roles and processes being quite different, and told as an example that residents in some countries are more actively involved already in the processes of construction phase in comparison to Finland.

"I think what we have seen is that without the developers buying into the case and driving things, then it's quite challenging, because they are the ones that actually make it happen. The architects will push and say that they want to have design like this etc. The developer makes the final call on what do they want to really do. Which material do they really want to use. So, it's the developer finally and then the developer is often the land owner and the land owner is in the driving seat in many cases." - M3 citation

The quote about the developers' dominant role in decision-making reveals that they have the final word over the designs of architects. Within the dynamics of the construction sector, the subcontractors are often the most hard-pressed to meet the demands of developers while keeping the costs to minimum. Thus, the tendency to prefer the easiest and cheapest construction processes is usually prioritized, as the contractors face the pressure to win tenders from the developers. Moreover, at the time of boom economy, when a lot of contracts are available, it is difficult to stipulate any extra conditions or constraints about how the construction should be performed. Also, the proliferation of modular buildings is increasingly shifting the power to the element producers. As can be seen, the power and influence within the construction sector is scattered between all the actors one way or another. "It's a patchwork, the result of everyone's expectations and requirements," as interviewee C5 expresses the situation of the construction sector.

"Everyone gets off easier in the construction business, all the construction permit architects and all when things get done as they have been usually done and approved, so that no one screws it up." - C4 citation

A more cynical perspective is presented by interviewee C4, who perceives the construction sector to be too stagnant as the actors are avoiding any unnecessary risks. A striking example shared by the interviewee was from a fellow architect, who continues to design the same type of schools as before, which are prone for mold infestation, since the construction companies and developers choose to use the same methods and processes as before. Interviewee C4 suggested that municipalities should take a much stronger and bolder stance in demanding new type of building solutions to end the chain of circumstances that construction sector actors have locked themselves in.

Next, the wood construction will be discussed separately as potential alternative building solutions.

Table 4.2.1.1. Summary of the most relevant findings about the dynamics in the construction sector.

Dimension	Circumstances of the Construction Sector - Insights
T	Long time-span of constructed environment.
T, S	Established processes and a few dominant actors.
S	Lack of communication between construction and maintenance companies.
T	Difficult to benchmark or adopt practices from other market areas.
S	Architects have less influence than in many other countries.
S	Developers & clients have the most influence.
M	Contractors have low profit margins and face strong competition.
G	Municipalities should support new types of building solutions.
T=Technological; M=Market/Economic; G=Governmental/Legislations; E=Environmental; B=Behavioral; S= Societal	

4.2.2 Wood Construction

Traditionally wood-based construction has been prevalent for single-family detached homes in Finland, whereas large-span constructions usually have been cast with concrete. Interviewee C4 is an architect specialized in solid timber construction and renovation and the discussions with him suggested that their workflow was far away from mass-production model typical to large-span structures, but instead their projects required active collaboration between involved actors such as carpenters and timber log contractors to ensure smooth processes. However, new technologies and products have made wood more substantial option besides to concrete, steel, bricks and other materials. Especially CLT (cross-laminated timber) was mentioned in several interviews. Most of the comments were positive, but couple critical views were also divulged.

"Wood construction has been supported even by the government for the last four or five terms and it hasn't been going that well. I don't mean that people would have done something wrong. Using wrong arguments, that may provoke counter reactions." - C1 citation

While the motivation and ideology behind the wood construction often emanates from sustainability and "environmental wisdom" as it did in several of the interviews, nonetheless interviewee C1 raised concerns about the validity of such arguments. One side of the problem is the requirements aside from carbon footprint that must be fulfilled both technically and functionally. Yet according to interviewee C1, significant amount of timber is already used in normal concrete and steel buildings as paneling and so on, and this is one factor contributing to the amount C&D waste. Because of the joint and other construction techniques, the reuse of the wood elements have proved difficult and faster wear out leads to additional renovation costs for example in floors in comparison to other materials. Interviewee C1 argues that manufacturers plan their produced wood materials for disposable one-time use in the first place.

The aforementioned interviewee C4 represents more purist thinking in wood construction, but C4 agreed that industrialization has turned buildings disposable, either to be incinerated or transported to a landfill. Architect C4 only uses solid timber in their projects and rejects combining several materials such as wool insulation. Thus, C4 was also skeptical of CLT, as it could be considered a sort of wood composite of wood and plastic glue. The reasoning behind the strict stance is the complexity that composites and mixes of construction elements creates, which may cause unforeseen problems for the air quality and create water damages. Additionally, combination of materials makes deconstruction and reuse of materials more challenging compared to using only solid wood.

Opinions on the matter vary, and interviewee C1 maintains that best solutions are achieved by combining different materials for the most efficient outcome. Again, finding a consensus for such a polarizing topic would be impossible. However, these downsides presented help to understand that wood construction processes and business models are still open for new ideas and innovation.

"Once wood construction becomes more popular, then national know-how probably starts to increase. Those synergies will become stronger also in education, where a positive cycle

materializes... ...there is no specific one business model for wood construction or one sensible business ecosystem. It is based on what techniques are used and what kind of actors are needed." - O2 citation.

Indeed, the general opinion from the interviewees seems to be that wood construction business is still in early stages. Interviewee O5 voiced a concern that progressing wood construction has felt to be detached from the rest of construction industry, whereas construction materials should be examined neutrally depending on the use case.

A dose of optimism was shared by interviewee F1 that wood construction and bioeconomy seem to hold almost endless possibilities, since smaller and smaller parts and sidestreams can be utilized for new products. New chemical properties are still being discovered. Likewise, interviewee C2 considered the possible advantage of CLT and timber elements to be faster construction times. Additionally, new wood composites are being utilized for wood construction. Interviewee O2 mentioned Lakea's Sydänpuu composite of concrete and wood as one new concept.

Still at the moment, wood construction seems to remain a marginal business. Much more investment to new production facilities would be required to be able to match concrete on any level. Yet, this may be about to change, as interviewee O6 implies that growth is increasing in residential multi-story constructions, and that would be the direction to seek for growth as the market has already been saturated with wood construction solutions in small residential building market. Some evidence of support exists also from municipalities, as O7 shared town planning efforts that have wooden buildings as a requirement. Also, O2 shared a story of a municipal manager pushing for wood construction projects. Apparently, the efforts to promote wood construction have helped, as some new actors have emerged. In fact, interviewee M3 said that both LVL (laminated veneer lumber) and CLT materials have become a credible alternative for six to ten story buildings, as they can have the advantage of being more efficient time-wise.

Indeed, wood construction seems to hold great promise in the future. However, the role of wood construction in cascading C&D waste timber seems to be still uncertain. Next, we will discuss the situation of waste management and related circular economy companies.

Table 4.2.2.1. Summary of the most relevant wood construction findings.

Dimension	Wood Construction - Insights
T, M	CLT elements becoming more popular in multi-story construction.
T	Construction material should be decided based on the technical and functional requirements.
T, E	Long-term quality and sustainability of current wood construction trends may still be uncertain.
T, M	New innovation and business models are still expected to enter the market.
T, S	Reusability of timber material has been acknowledged, but has not apparently received any special consideration in wood construction.
M	Wood construction for large-span constructions is still marginal, but showing signs of growth.
T=Technological; M=Market/Economic; G=Governmental/Legislations; E=Environmental; B=Behavioral; S= Societal	

4.3 C&D Waste Management

Demolition is seen as necessary evil in the overall construction project to make way for a new building. Interviewees O1 and E1 contend that because of this, the demolition is usually completed in haste with a tight schedule. The result of this is a pile of rubble that needs to be sorted afterwards. Since demolition costs only a fraction of a construction project, this could also be why the developer or client could be willing to pay little extra for the demolition to make it more sustainable. That is what the organization of E3 seems to rely on as they have introduced a possibility for some additional costs to ship waste wood abroad to process it to particleboards.

However, the challenge for demolition contractors would appear to be the sorting and maintaining the quality of waste streams for their next purpose. Additional challenges for demolition and onsite sorting is created by restrictions of available space and regulations especially when operating within cities. The efficiency of onsite activities is increased with the collaboration of demolition and waste management companies, as they create waste management plan for sites.

Interviewee O4 believed demolition companies to be crucial in discovering new partners that they could provide their waste stream by ensuring its quality. Yet, apparently wooden buildings are not demolished that much at the moment relatively to other type of buildings, but the reason for this seems to be uncertain. Interviewees E1 speculate that the wood-based construction could be more endurable than alternatives. Interviewee E3 also said that renovation sites produce the least wood waste, while new construction sites produce the second and demolition sites the most.

"So, yeah recyclers. You need demolition experts, recyclers and then users of that recycled material. So those are the three main players you need to have. And that effectively comes for demolition and also then on-site waste. If it's onsite waste, then it's recyclers and re-processors. If it's end-of-life, then it's demolition and recyclers and re-processors. The challenge as always is the tyranny of distance and availability of material, continuity of material supply, because you need to have critical mass of material to make it viable for recycler to bother to recycle it and you need then critical mass of material for re-processor to process it." - M3 citation describing whose collaboration would be required for reuse or recycling of C&D waste timber

The quote by interviewee M3 gives a summary of the situation regarding C&D waste management industry and also the forces driving the industry. In the first stage, demolition companies dismantle a building of which material they sort as efficiently they can to separate valuable material from worthless waste. These material streams are then either sold or paid for processing facilities and waste management companies to process or sort further until the material streams reach their final destination, whether that is landfill, energy use or new products.

Furthermore, interviewee C1 considered the reuse of building products to still be small scale, which is mostly practiced by some hardware stores and renovating individuals. One reason causing the difficulty of scaling the reuse and recycling was partly credited to irregular supply of the waste material streams, as smaller volumes can originate from renovations, while bulks of material can suddenly come from a demolition site where the material has been part of a building possibly over fifty years or more. Erratic supply chain can be problematic for the logistics of waste management.

Nevertheless, interviewee E1 finds that legislation is pressuring the waste management companies to meet the ambitious goal of waste directives to increase the rate of recycling. This also burdens the actors to make changes in their activities, although some interviewees such as M1 believed the current goal to be too high to be realistic.

While meeting the goal of waste directive may be a great concern for the actors of the waste management that does not automatically mean that they would prioritize cascading of waste timber. This may be true, since the waste directive for the recycling of 70% of C&D waste does not specify any material, as interviewee O3 pointed out. Especially since the waste directive is measured by weight, actors might have more interest to concentrate on recycling other heavier materials. Additionally, concrete is usually considerably bigger stream of waste material produced from demolition sites which was also emphasized by a few interviewees. Interviewee E1 explained that the logistics of their sorting equipment forces them to prioritize between materials. E1 also considered plastics to be a greater concern for them, as they are more difficult to sort and waste timber already has an end-of-waste location with energy use. Thus, waste management seems to be more concerned by other materials.

The current phenomenon in waste management industry seems to be consolidation of actors to bigger organizations, as was highlighted by interviewee E5, who implied that the industry is going through a critical period. It remains to be seen whether or not the restructuring of waste management industry enables it to become more efficient. Perhaps, one way would be to have the material transferred to use before the material is defined as waste, since waste regulations prevent from reusing the material in certain ways and even energy use is allowed in plants that have the license to burn waste timber.

What seems to be missing in the industry and the ecosystem is the destination to transport the C&D waste timber so that the rate and grade of recycling would increase. Interviewee E4 attests that construction companies along with waste management companies would be willing and interested to recycle and sort the material stream so that it would retain higher value, but alas no such prospects have emerged. Some marketplaces, recycling centers and special stores exist, but they can hardly handle the overall quantities of material available, as the interviewee pointed out. Further constraints are imposed by the regulations that determine storing of waste for more than three years to be landfill, which means that waste and landfill taxes will be levied. Therefore, waste management actors have mostly been bound to send the timber waste to energy use.

"Actually, I see it the way that we make the sorting options so, if just somebody develops something where we can deliver them. In fact, usually some facility contacts us and suggests material that they could receive. If it ends up working, we can try to change our sorting options to match it... ...Someone else has to develop the solution and we just supply the material" - E2 citation

Excerpt from interviewee E2 indicates the conventions of waste management that the alteration of supply chain and end-of-waste destination has to be managed by some other actors. But interviewee M3 also argues that economic modes of Finland introduce little stress to recycle, as Finland has abundance of virgin wood material available and the consumption of the resources is relatively low in comparison to other countries that are net importers causing them to experience stronger economic burden of acquiring material. Hence, little incentives seem to exist to innovate higher value of reuse and recycling for C&D waste timber in Finland.

The following part inspects the insights that interviewees considered relevant to share regarding cascading timber itself.

Table 4.3.1. Summary of the most relevant findings in regards to C&D waste management

Dimension	C&D Waste Management - Insights
M	Demolitions are finished in haste preventing proper deconstruction.
M	The cost of demolition is marginal compared to total construction costs.
T, S	Demolition actors need to find and convince potential partners of the quality of waste stream.
T, M	Low volumes of waste wood from demolition sites.
T, M	Irregular material stream of waste wood available to supply.
G, S	Waste wood weighs less than concrete, steel and soil, so it is considered less important to meet the goal of waste framework directive.
M	Trend of waste management companies consolidating is ongoing.
M	Actors and destination for higher value reuse or recycling of wood does not exist in the market, which forces actors to send their material to energy use.
M	Waste management actors are unlikely to create alternative channels and solution for C&D waste timber themselves.
T=Technological; M=Market/Economic; G=Governmental/Legislations; E=Environmental; B=Behavioral; S= Societal	

4.4 Conditions of Cascading Timber

Before delving further to discuss the identified barriers for cascading timber, a general overview of the current situation around cascading C&D timber waste is reviewed.

Overall, regarding the material stream of timber, all actors naturally aim to enact material efficiency to the best of their capabilities. This is why often only the lowest grade waste material arrives to recycling centers and to waste management actors, since the most valuable material has been harvested for further use. Interviewee E2 said that this makes it difficult for them to reuse the "reject" material.

The standard procedure for C&D waste timber seems to be to store the material in their own piles and to amass as much material until a transportable wood crusher is brought to crush all the timber material. Interviewee E5 also said that if the crushed timber is used as solid recovery fuel, then the material can even be stored outside, but if it will be used as raw material for fiber boards, then it has to be stored inside.

Interviewees E4 thought that there are not that many incineration plants, which are allowed to use waste timber. Scarcity of plants then results in longer distances for transportation. Yet, all the interviewees from waste management organizations told that energy use is the primary source for waste timber at the moment. Some exceptions exist of which Destaclean was mentioned as a company that processes waste timber material into new wood composite products, but most of these alternatives seemed to be marginal in scale. Interviewee E3 also explained that their organization reuses and repairs wooden pallets for multiple uses, although applying the business model of wooden pallets to C&D waste timber might be difficult. Instead the same organization provides an option for their clients to ship wood waste to Central Europe where a fiber board factory recycles the material.

Reusing of timber and other building materials can be grouped to two categories according to interviewee O3. These two alternatives are either disassembling a building to the most basic components as they originally were or reusing whole elements of a building. The first option could be considered more versatile, as the material could be used for various purposes, whereas a whole element would often need to have predetermined purpose and destination while the workload to dismantling is lower. The element reuse would seem to be characteristic in construction and renovation of traditional solid timber houses, which was supported by accounts of interviewee C4 who specializes in architecture and planning of such houses.

The basic phenomenon hindering reuse and recycling timber is its rapidly decreasing value in comparison to other materials such as metals that are easier to reutilize with melting processes as interviewee E1 explained. The technical factors and properties contributing to the decreasing value of timber are explored in the following part.

Table 4.4.1. Summary of the most relevant findings about the situation of cascading C&D waste timber.

Dimension	Conditions of Cascading Timber - Insights
T	The reusable material is reutilized already before waste management, so the remaining waste material is often too low quality to be reused anymore.
T	C&D waste timber is stored in piles for long periods until crushed and delivered forward.
T, E, M	Energy use is the primary destination for all C&D waste timber material.
G	Yet, not that many incineration plants are allowed to burn the waste material in Finland.
T	Two categories of reusing: Basic components or elements.
T, M	Waste timber has lower value compared to materials such as metals, as they are simpler to reprocess to new products.
T=Technological; M=Market/Economic; G=Governmental/Legislations; E=Environmental; B=Behavioral; S= Societal	

4.5 Feasibility Constraints

Multitude of constraints against cascading C&D waste timber has been identified from technical processes and logistics to material quality and chemical properties. All in all, the cascade of barriers seems discouragingly overwhelming. Herein an attempt is made to create more coherent awareness of the different constraints that maintain the current status quo in the business ecosystem and what are the greatest concerns for actors.

C&D waste timber has a tendency to contain small bits of metal, such as nails and screws used to connect the component in its original purpose. This would be a problem, if the material would be reused as the same material, since any inside tree could damage saw blade. However, the problem in the industry has been eliminated by crushing the timber to chips as the quote below by interviewee E1 demonstrates.

"Magnetic metals don't end up in wood chips much at all anymore. If something is there, it's crushed so small that all of it practically comes out there. But what stays are aluminium and other non-magnetic metals. These are stainless steel screws and such... ...We are going to have a new machine that removes even the aluminium." - E1 citation about their companies processing of timber waste.

Thus, even energy use of timber waste requires multiple processes before it becomes usable because of the processes in the construction phase. The sorting prior to crushing adds another layer of complexity to cascading. Already in the construction stage, several materials in addition to timber may be connected or layered to each other, which makes efficient reuse even more difficult. Researcher O3 reminded that connectors are usually easier to attach than detach, which means that the ends of timber components would often have to be cut leaving shorter components left and loss of material. At least interviewee C3 thought that walls and bottoms of the elements in their company solutions would be possible to deconstruct as element parts, since they are connected to other elements with screws, but dismantling a wall itself to components would not be feasible. Thus, reusing elements could be more feasible than reusing basic components when assessed with time and labor efficiency.

"The instance when wood waste goes to material utilization, it tends to be side stream of the forest industry. This construction wood waste is seen as more difficult, because the quality is not consistent in anyway. A demolition site might have fungi-infested board; there can be boards with nails or paint, whereas the side stream of forest industry is more consistent." - E4 citation listing a few of the issues contributing to the inconsistent quality of waste timber.

The excerpt from E4 interview shows that effective sorting of wood from other material may not be enough, as variety of waste wood can lead to categories of quality that should also be sorted to identify the most appropriate use case for them.

"It's completely different thing when the building is hundred years old if it's been built in 60s, 70s, or 80s, as the material cocktail is completely different and this will have an effect long into the future. There will be different kind of materials connected differently and treated differently." - O5 citation

Securing C&D waste material with consistent quality will not be feasible even in the near future. Architect C4 explained that the original time period of building has a huge impact regarding timber quality when renovating old wooden buildings or reusing material from deconstructed buildings, where for example houses from time period 20s and 30s contain more impregnated timber that they deem unusable. Therefore, this constraint of wide divergence in C&D waste quality has to be taken into consideration when gauging the potential of cascading timber material.

Another instance of the sorting problem concerns the chemically impregnated wood, which itself prevents problems such as rotting and fungi, but it has to be sorted separately as hazardous waste in end-of-life. Interviewees E1 said that their company will not even accept impregnated wood to their sorting stations and they monitor that deliveries of waste do not contain the aforementioned material. In the past, such treated timber have been exported to Germany for energy use, but companies such as Demolite are starting to deliver the material to a new specialized energy plant for incineration within Finland (Leponiemi, 2017). Reusing or recycling impregnated wood could be quite difficult as it would have to pass end-of-waste process, as noted by interviewee O3.

"It would be extremely difficult for us. We need exactly certain sized preprocessed boards that we use to put together floors and walls. I don't know if we could get that kind of board; there are after all specific strength attributes that have to be met and proven by calculations." C3 citation about the prerequisites of material for the construction sector

Construction companies are liable for the quality of their constructed buildings. Reusing C&D waste within the same construction industry where the waste material originated from is faced by the challenge of being able to conform to the expected quality of raw material. As discussed before, waste wood providers may not be able to make such promises.

Furthermore, grading standards for reusing C&D waste timber do not still exist. Interviewee O3 explained that at the moment only option in Finland to reuse the waste wood as construction components would be to have the material tested in a certification laboratory apart. The exception would be cases where sawn timber material has been produced for personal use for example own house, which would not be a commercially viable option (Confederation of Finnish Construction Industries RT, 2012).

"It is definitely going more towards the direction of serial production and standardization all the time. So pieces of board are not used to pile up a flat, but instead these kinds of production processes are used where logistics intertwines everything so that all kind of gains are achieved through them." - C3 citation

Interviewee C3 elaborates on the reality of construction and manufacturing industries in how they are aiming to increase the efficiency of their activities. On the other hand, interviewee C4 argued that standardization and the requirement of CE marking for construction timber has made the quality of available material worse, as smaller sawmills are unable to provide CE marking for their supply that could be both better quality and have shorter distance for transportation. The next part scrutinizes how such factors as cost efficiency and profitability affect the potential of cascading timber based on the interviewees experience and opinions.

Table 4.5.1. Summary of the most relevant findings in regards to the feasibility of cascading timber.

Dimension	Feasibility Constraints - Insights
T	C&D waste timber contains often both magnetic and non-magnetic metal that has to be removed along with crushing the material.
T, M	Sorting timber from other waste material tends to be labor-intensive
T	Timber from demolition sites vary significantly in quality and quantity based on the type and age of demolished building.
T	The wood quality is affected by many factors, such as metals, fungi, paints, chemical treatments etc.
T	Reusing elements instead of components might be more feasible.
T	Construction sector seems to be hesitant to reuse waste material, as homogeneity of material and constant supply are prerequisites for business activities.
T, G	No standardization procedure for reusing C&D waste timber seems to exist or has been adopted yet.
T=Technological; M=Market/Economic; G=Governmental/Legislations; E=Environmental; B=Behavioral; S= Societal	

4.6 Economic Viability

The issue that was the most frequent of all topics, and was mentioned in every interview, was the economic aspect of profitability and cost efficiency.

"We have to make as profitable business now as the last accounting period was. So we have to ensure the customers' willingness to pay and now we are speaking about the construction companies. If they are ready to pay for recycling then we deliver." - E3 citation.

The quote above illustrates that every actor has to first and foremost consider the bottom line before advocating any other causes. The example mentioned by interviewee E3 concerned only the increased costs to recycling of wood waste for fiber boards instead of other cheaper options such as energy use. But the principle extends to all the industries in the value chain. For instance, the dilemma of cascading timber stems already from the manufacturing, since they practically sell the product for one-time usage and do not usually consider or care what happens to the material beyond its original utilization. Construction sector might have equally low incentive to invest in new processes allowing easier reuse of materials, when their profit margins are already thin, as attested by interviewee C1.

This simple fact of cost efficiency has itself changed operating environment of construction sector to prefer concrete buildings over wood construction, as interviewee O7 revealed that competitive tendering made the former construction method the preferred option in the early 2000s. Also, concrete-based construction was more standardized than wood construction making it even cheaper and safer choice. Nowadays, the situation has become more a bit more even, and some cases of wooden multistory constructions exist in Finland.

"This is also very general answer for all materials, so the most important is owner, because he needs to have idea either that he is building from something reused or is building something that will be reused in the future. So in economic terms, he can have motivation of having higher value of his building at the end of life, so if he is planning to sell some parts in the future, he can say, I don't know is it called depreciation or what is this economic term, is slower in his building, which is profitable for him. So he can have some motivation on that and he is usually the one who is starting the discussion about reusing." - O3 citation

The excerpt from O3 highlights the crucial role of building owners in cascading material streams. The motivation for all rational actors would be to maximize their profit. So why have not owners reacted to ensure that the building retains its value even in the end of building lifecycle?

Interviewee C5 thought that actors in Finland have inclination to choose option that is cheaper in short-term but more expensive in long-term: "The difference between cheap and economical is not recognized much here. So cheap is cheap, but economical may cost more now but looking at the whole lifecycle, the costs end up being smaller. So kitchen that cost twice more but lasts three times longer, so it ended up being more economical." Perhaps the same issue applies to thinking and processes that prevent the preservation of higher value of material.

Thus, the issue would have to be possibly approached on a structural level of the ecosystem to reach all the actors to participate in the development and share the responsibility. Interviewee E5 thought that no actor was to blame, but instead the market for circular economy is still waiting to mature, as the economic value of recyclable material continues to be lacking. The formation of a new kind of value chain would be required to realize this kind of circular economy.

The value chain and business ecosystem are flawed at the moment according to interviewee O4, who seems to share some of the same sentiments. O4 considers one issue hindering circular economy to be in the valuation of material in the waste management phase, starting already from demolition. As demolition is contracted to a company and paid to dispose the material and they in turn might pay a sorting station, the value of material has become reversed, since the material is perceived to have negative value. Instead, the circular economy could become reality if an actor paid for the material of a demolition site and continued the value chain by selling the material forward at a higher price. Interviewee O3 elaborated on the same concept with stockist actors who hoard heaps of metal, which they sell once the price of material goes up in the market. Such reconfiguration of value chain may be overly idealistic still, since the value of timber is low in Finland regardless whether it is new or old. This seems to corroborated by statement of E3 that their waste management organization needs to charge higher gate fee for material utilization compared to energy use of waste timber, although the reason for this at least partially is the shipping to abroad for a processing plant.

The feasibility constraints discussed earlier and matters of economic viability are deeply interconnected. Few of the problems are impossible to execute technically, but the actual problem resides in the cost efficiency. Sorting timber, cleaning the timber and removing nails, screws and other metals are all possible to do, but they all share the trait of being labor-intensive. As interviewee C3 said: *"Because labor is so expensive in Finland, you can't use much time to fix [waste timber] or cut to right size. The cost structure has to be kept as small as possible, so if recycled material wanted to be used, if should be extremely easy, so it doesn't cost more."* One option would be to utilize machinery to take care of sorting and cleaning processes, as interviewee C3 suggested, but these also require investments that could possibly never yield returns.

"So, yes the end-of-life question is there and it's an opportunity, but I would say that it is not yet the primary focus of construction companies, architects or developers. Their primary focus is on speed, renewability, energy efficiency; these are the key drivers of utilization at least today. End-of-life management is a thing which is taken into account, but it's not business critical at this stage." - M3 citation

The quote by M3 explains the priorities of actors operating within the conditions of market economy. Cascading C&D timber waste and other circular economy practices are below many other factors that take precedence in actor's daily activities to ensure and maintain the vitality of the company. The next section will discuss further how the political, sectoral and organizational will to drive change is affecting the playground.

Table 4.6.1. Summary of the most relevant findings regarding the economic viability of cascading timber.

Dimension	Economic Viability - Insights
M	Profitability and cost efficiency are the top priority for all companies.
T, M	Timber products manufactured for only one-time use.
M, G	Wood construction less standardized than concrete.
M, B	Building owners have major role to redefine the value at the end of building lifecycle.
M, B	Decision-making often based on short-term profits over long-term gains.
T, M	Better sorting of timber too labor-intensive to be cost efficient.
T, M	Reconfiguration of value chain and valuation of material stream is required.
T=Technological; M=Market/Economic; G=Governmental/Legislations; E=Environmental; B=Behavioral; S= Societal	

4.7 Political, Sectoral & Organizational Will

Every actor in the business ecosystem has their own interests to look after as we have discovered through the myriads of problems in the problems that have so far been discussed. Several different forces are both pushing forward or against the transformation towards circular economy and, consequently, cascading timber. In this context, some opinions and observations of the interviewees are scrutinized to attain understanding how different policies, influence and attitudes affects the ecosystem and how they could change it.

"...looking from my perspective, the construction industry is quite competitive, so there seems to be constant arm wrestle between materials. This involves quite a lot of lobbying and similar things. Certain manufacturers of materials have pretty strong lobbying towards policymakers. Usually, it has appeared, not quite quarrelsome, but that co-operation has not always been smooth to outsider's eyes." - O5 citation

Lobbying power of sectors towards the regulatory bodies can create the bounding frames for operations with regulations in their favor. Furthermore, such behavior can divide actors further apart and induce disputes between competitors, if one pool of actors feels that another group of actors in industry have an advantage in policies. Interviewee O2 had the intuition that timber manufacturing industry may perceive circular economy practices as a threat to their business. For example, construction product manufacturers associations in European level may hinder the support towards circular economy in integrating the principles to Construction Products Regulation, despite policymakers in European Commission otherwise being favorable towards circular economy, as suggested by interviewee O3. However, the lobbying organization for wood product industry in Finland has supported and researched the reuse and recycling of timber material, as attested by interviewee M1.

One example of a policy that would seem to be partially in favor of cascading C&D timber was new regulation of R-value measuring the level of insulation, as cited by interviewee C4. Indeed, the major reform of regulations for construction sector in Finland coming into effect in the beginning of year 2018, continues to have reliefs for log buildings and introduces the same relief to massive timber construction of requiring R-value of 0.57 or less, whereas the value to other materials is 0,17 or less (Mölsä, 2018). Thus, the policymakers in Finland have demonstrated in some instances to at least support wood construction and reuse of massive timber elements, but the matter of reusing waste timber may differ, as several interviews pointed out, that a report by Ministry of Environment determined the energy use to be the best option at the moment (Manninen, Judl and Myllymaa, 2015).

The wood construction has gained some traction on certain municipalities, as interviewee O7 explained that zoning in their city has been used to obligate wood construction in a couple districts on the basis of environmentalism. Similar stories were shared by a few, but the commonalities shared were the level of scale with these endeavors, of which most could be considered pilots and experiments while steel and concrete construction retains its dominant position in large-span buildings. A useful insight provided by interviewee O7 was that zoning can determine and enforce also reusing of material, and there have been some examples of that with other materials like stone material. However, such zoning specifications apparently can stand only for 15 years.

Overall, the construction sector actors and several other interviewees concluded the municipalities and their zoning and building inspectors to possess great power in dictating what is built and how it is to be constructed. However, the problems arise from the disjointed decisions and requirements between municipalities. This may on the other hand make it difficult for element manufacturers and construction companies to standardize their products and practices. Nonetheless, interviewee O7 pointed out that even municipalities have to conform to the laws and norms established by Ministry of Environment, which also affects zoning with Land Use and Building Act. Thus, the decisions are political both on municipal and national level. Additionally, cities and smaller town differ greatly in their practices and needs for construction, which would make it difficult to standardize zoning between municipalities.

Municipalities, land and building owners and developers have not been that interested in to initiate wood construction projects, since that would limit the amount of actors able to participate in a tender. Also, the wood construction has been less standardized and common, which would most likely increase the costs of construction even more.

However, interviewee O3 argued that to promote reuse of C&D waste in the European Union, it would be more productive to employ pull from market instead of pushing with policies, since member states might react negatively against additional regulations. In general, most of the interviewees, and especially the industry actors, thought that the change towards circular economy should not be artificially enforced with new regulations, but on the contrary the market and demand dictates the best practices. Interviewee O6 reminded that Finnish government has promised to unburden the legislation instead of increasing the amount of regulations, which would support the market-based ideology.

"Waste industry is awfully contentious. Everything has to be decreed by law because of that, so that we can get somewhere...

...All of us work with other companies and it works. The quarreling happens where the laws are made and that's why vague laws are decreed as there is the arguing about who is allowed to collect what waste. Then the laws are produced in a fast pace." - E2 citation

The competition and low levels of collaboration might also play an important factor within the waste management industry in impeding the circular economy. Interviewee E2 claimed that the industry actors do not have especially healthy relationship with each other, as everyone is looking after their own interests in securing market shares. Hence, the lack of collaboration and fragmented lobbying may not yield the optimal results for the treatment of waste material. Interviewees E1 considered additional regulations to complicate their business, whereas E3 had the point of view that all regulation promoting the recycling just supports their business. Thus, many facets and little consensus seem to exist regarding waste management legislation.

The complexity and difficulty of reusing and recycling C&D waste seems to be one contributing factor that prevents the progress of circular economy. Interviewee E1 contemplated that the current requirement for environmental permits to processes, such as crush material onsite, hinders the activities, as now the material has to be transported to separate location for processing before it can be shipped to a new location for utilization. Therefore, additional steps in the process add to the costs, which make the utilization of material less lucrative.

On a sectoral level and market-driven approach that seems to be preferred by interviewed actors, the developers and land owners have the key role in deciding the both the construction materials and how the building will be treated in the end-of-life. However, as earlier part about the economic viability discussed, the decision-making of these actors is primarily driven by profitability and cost-efficiency. Neither wood construction nor reusing C&D waste timber seems to coincide with such criteria.

The importance and priority of plastics and their recycling was already raised in waste management section. In comparison, interviewee E5 thought that recycling of timber could have hardships to attain the same level of appreciation, since more work would have to be carried out to systematically develop the value chain, so that the recyclable streams can be identified and utilized. Also, the volume and value of these potential streams was raised to question, as E5 questioned the viability of producing and shipping the waste timber to wood chips as the current practice seems to be. This type of low value wood material may be available in abundance in most countries already. A few other interviewees shared the skepticism towards importing waste wood material abroad as a non-sustainable option.

Yet, interviewee E3 thought that the current waste directives will guide construction companies to contribute to reach the recycling and recovery targets by shipping crushed waste timber abroad for fiber board production. This may indeed be an alternative option, since interviewee E4 reminded that only a fraction of energy plants have the permits to use waste timber. Thus, energy production may have only limited capacity for waste timber, which is also determined by the price of other sources of energy fuel material.

All in all, regulations exist for a reason. Their purpose is to protect something, which are usually citizens. Hence, interviewee O4 argued that legislation does not hinder cascading of timber any more than it is necessary. To elaborate, old C&D waste timber can contain various hazardous substances, which is why regulations restrict the usage of waste material. Essentially, regulations minimize risks by defining the rules for practices that prevent the use of harmful or unsafe material. Such regulations introduce certain repercussion to the market, as interviewee C4 mentioned about the difficulty and costs of acquiring CE markings obstruct smaller actors from selling their timber products for construction purposes. Interviewee E5 had the opinion that circular economy challenges current interpretations of legislation. Thus, stronger regulations and standardization can have the consequence of creating a barrier and economic moat for new actors to enter the industries, which in turn might prevent new kind of business models and approaches from succeeding. However, most could not name any examples of legislation that would hinder cascading of C&D timber.

The attitudes regarding circular economy seem to be strongly divided among the clients of waste management sector, according to interviewee E4; some are extremely interested and invested in recycling their waste, while others have more pessimistic view about how their actions would have negligible impact in the grand scheme of things.

While the problem of finding better use for waste timber has been acknowledged, several of the interviewees conceded that it is low priority to them, when compared to other problems. Interviewee O3 thought that even if the industry recycled no waste timber, they could still meet the goal of recycling 70% of C&D waste by the year 2020, as they could concentrate on concrete and other heavier materials. The abundance of natural resources of timber also seems to impact the attitude towards recycling waste timber. Interviewee M2 stated an interesting point that the majority of sawn timber is exported to other countries, which already makes the case of waste timber inside Finland seem less far-reaching. So, there is not a significant pressure to cascade waste timber either from scarcity of available resources or discover new end-of-life options to energy use in Finland. In this context, reimagining the business ecosystem to enable more effective reuse and recycling of timber does not seem to be an easy task and perhaps not even vital.

However, all the interviewees working in the business ecosystem expressed their interest towards reusing and recycling C&D waste timber. Everyone from the waste management industry told that if there was an alternative destination to energy use of timber that would be higher in waste hierarchy, they would have interest to partner with such actors. Yet, none of the already established actors in the business ecosystem saw that they could have the means to develop new use cases themselves.

"Often the biggest leaps require some directive or policy, so that things really start to take off." - O1 citation

"Everything depends on the mindset. If a political environment is created for the products, so that their reuse is possible and if that course is strongly directed with support processes and mechanisms, so that reused construction components are competitive in the market, and at the same support the know-how of the industry and solve related quite huge logistical and warehousing issues, then it could happen. There are many things that would have to be developed simultaneously. It would require strong guidance and it is difficult to see that the market alone would solve this issue." - O6 citation

As interviewees O1 and O6 propose, some sort of imperative would be necessary to actualize new kind of approaches to reusing C&D timber waste and circular economy.

Next, a brief look will be taken to the effect of design phase and how it could enable cascading timber waste from the other end of the value chain.

Table 4.7.1. Summary of the most relevant findings related to the political, sectoral and organizational will to encourage and promote cascading of C&D waste timber.

Dimension	Political, Sectoral & Organizational Will - Insights
G	Lobbying organizations and companies of construction sector and waste management industry are all trying to influence legislation to match their interests.
G	New regulations of construction sector seem to support wood construction.
G	Municipalities and zoning could enforce rules for construction materials and reusing them, although rarely applied in reality.
G	Some municipalities advocate wood construction, but the field is scattered.
G	Zoning and construction policies in municipalities vary significantly.
G	Most agree that the change to recycling practices should come from the market and industries themselves.
B	All actors expressed interest towards new solutions and actors that would enable reuse and recycling of timber.
B	Yet, no actor seems particularly interested or willing to innovate new solutions.
B	Many perceive the issue of recycling of C&D waste timber to be miniscule problem in comparison to other material streams.
G	Legislative power seems to be the only option to enforce greater change for reuse and recycling of C&D waste timber.
T=Technological; M=Market/Economic; G=Governmental/Legislations; E=Environmental; B=Behavioral; S= Societal	

4.8 Impact of Design

"I see that it is the design in how the building was originally built, its influence is extremely significant and it is not yet quite understood." - O1 citation regarding which actors have the most influence in the business ecosystem.

The barriers and drivers to cascading C&D waste timber have been examined from various aspects to establish holistic understanding of the forces shaping the business ecosystem.

Yet, several interviewees acknowledged the significant role of design and planning in redefining the processes and driving change. Some of those findings are discussed below.

The design can be restricted by economic factors already in zoning and architectural decision, if the property is so expensive that the only viable option is to construct a multi-story building. The location and consequent price of property often decides the longevity and sustainability of a building, as unprofitable buildings are demolished to make way for more profitable buildings, as explicated by interviewee C5. Such factors evidently set constraints for the design of buildings, which do not account in the environmental sustainability aspects at least yet.

They are not cast on site. I think one of the big, big challenges is cast-on-site construction, where there are no elements or no way of deconstructing. Only way is to get bulldozers in and tear it down or blow it up. Then you are left with a huge amount of rubble and dust and dirt, which then has to be managed, which is really challenging, I think so. So, I'm not sure how much work really needs to go into design for deconstruction other than making sure that the jointing methods are easy to then disassemble. - M3 citation

Interviewee M3 described one of the most significant benefits of element-based and wood construction over concrete construction. The convenience of deconstruction with timber material would seem much more plausible option, especially if already taken into account in design phase. Therefore, wood construction could be critical aspect of reusing C&D material in general.

"Now that new buildings are made, they should already in the design phase consider how to assemble modules and how it functions effectively, so that when the time for recycling comes, the modules are easy to deconstruct and transfer for the next purpose, and what eventually goes to energy use." - O2 Citation

The excerpt from interviewee O2 emphasizes the critical role of functional design especially in the future to implement the circular economy thinking to construction products and processes, which could advance the feasibility of reusing the material multiple times before coming to the end of cascading circle with incineration. Interviewee E1 concurred that the lifecycle thinking should be reckoned already in the construction phase, so that there would be a deconstruction plan prepared for the building end-of-life to enhance the reutilization of materials. Thus, the influence and awareness of circular economy and cascading should be involved more already in the beginning of construction projects to reap the benefits in the future.

In order to integrate circular design, interviewee O6 suggested that designers should have a stronger understanding of demolition processes to develop construction and jointing designs further. But O6 argued also that designers should likewise regard renovations as a process that will cause shifts of material, so a building should be designed with both renovation and demolition in mind and provide necessary guidelines and instructions for them already beforehand.

The role of digitalization and building information models seem to have a major impact in supporting the design work for buildings. Interviewee M3 explained how these systems have increased the flow of information, which has improved their expertise about jointing of components as one instance. But the more significant aspect is the improved communication and collaboration between actors, such as architects and specifiers.

Digitalization and information systems will become even more crucial, if and when designers utilize old reusable materials to new buildings. Interviewee O6 thought that recycling of materials might be significantly simpler in comparison to reusing, since issues such procurement, logistics, warehousing and construction processes will become more complicated due to sporadic supply of reused construction components from various sources. Thus, practically all the processes would possibly have to be redesigned to accommodate to the changed nature of material supply.

The challenge with the existing building stock, interviewee O2 remarked, is to recognize the ensemble of materials that the buildings consist of, and sort these material streams efficiently, so they can be redistributed for further usage. Interviewee O6 has identified there to be a missing link, of which the interviewee referred as pre-demolition auditors. These are consultants that would assess the quality and quantity of all materials within a building, and determine what is reusable and recyclable and what is unusable or hazardous. After this the deconstruction phase would be designed and executed so that the material streams are preserved in the best possible condition for further utilization.

Missing actors and other potential solutions will be the final part of findings, in which potential solutions and approaches for circular design of C&D waste timber utilization are delved deeper.

Table 4.8.1. Summary of the most relevant findings concerning the role and impact of design to enable cascading of C&D waste timber.

Dimension	Impact of Design - Insights
T	Design of a building is often constrained by the property.
T	Wood construction in itself enables better deconstruction compared to concrete.
T	Design should involve deconstruction for example with modularization and guidebook for renovation and demolition.
T	Digital tools and information systems have enhanced designing and communication between actors.
T	The digital tools might become a necessity to enable the reuse of old components in new buildings.
T	Pre-demolition auditors could be the channel to direct material streams for better usage.
T=Technological; M=Market/Economic; G=Governmental/Legislations; E=Environmental; B=Behavioral; S= Societal	

4.9 Progress & Reinvention

Almost every interviewee proposed that what is missing from the business ecosystem, are a new set of actors, who could offer higher value for C&D waste timber than the current option of incineration. However, most were not sure what these actors or solutions would be. A few solutions for the future were suggested, of which one was the pre-demolition auditors mentioned in the previous part.

While many of the interviewees mentioned missing actors, the most concrete example was shared by interviewee O6 about pre-demolition auditors that could improve the efficiency of demolition phase. No such actors seem to exist in Finland yet, at least with the specific term, and the aim of the government seems to be to encourage such activity instead of requiring it demolition phase with legislation. Thus, interviewee O6 elaborated: "we are compiling pre-demolition audit guide that is voluntary. We are trying to create good national policies and then putting them in practice around Finland." Pre-demolition auditor would also act as a third party between a building owner and a demolition company to evaluate the real value of material without anyone's personal interests affecting the valuation analysis. Pre-demolition audit seems to be analogous to material inspection that the organization of O6 has operated with several success stories in enhancing the efficiency of production facilities. Thus, pre-demolition audit might become an in important value-adding actor between construction and waste management industries.

A similar idea was proposed by interviewee O4, who also shared a story of such business in Netherlands, where the company sorts and stores material from demolition sites. Then the company sells suitable material to the actors that they have connected with via their network of potential clients. The underlying idea for the company is to beat the market by becoming profitable enough to actually buy the material from demolition sites, instead of getting paid to dispose of the waste material. Since even that company seemed to be quite new, the profitability and sustainability of such business model remains undecided.

However, the consensus seems to be that the lack of actors to drive the reuse of waste timber is the main problem as the quote below by interviewee O3 indicates.

"Technical solutions are... as I said we don't really need to take technologies. We need more business players or actors that are missing or we need to saturate the market probably, so that there will be enough offerings. And for this we can use some technologies." - O3 citation

Transmutation of the business ecosystem to become circular may require the actors and industries to alter their business models and operations all together. Interviewee M3 raised a valid point that rapid accumulation of waste timber material might be a greater concern for products with short-term lifecycle such as furniture, and M3 suggested that companies such as IKEA will have to transform themselves to also become recyclers of the material similar to what has happened with electronics stores receiving old electronics. But perhaps the same approach could be applied to construction waste, so that larger timber manufacturing companies would be obliged to accept old timber materials, so that they could reprocess the material directly. Such ideas once again are purely hypothetical.

Material efficiency in processes would seem to support both the profitability of businesses and cascading of waste materials. Therefore, such improvement practices would seem the most likely to progress in the future, which is also what interviewee M3 agreed that products will become more engineered and processed in factory environments, so that less material wasted or required on materials. The key to material efficiency and also reusing would seem to be standardization of constructions and thereupon the modularization of buildings. Forming industrial symbioses between actors to improve material efficiency has already been advanced by the organization of interviewee O5. These symbioses are already one type of industrial ecosystems, where material streams are optimized between organizations to increase the productivity of operations and minimize costs

The proliferation of wood construction with materials such as CLT are going to change also the waste management and recycling conventions in the future, as the composition of waste material will have more substantial material stream of timber in the future. Interviewee O7 thought that once the impetus for wood construction has been initiated with zoning requirements, the infrastructure around wood construction will expand and become more viable business. Nonetheless, construction sector is slow to transform, which is why interviewee O3 estimated that the change in practices will become more evident in 20 years or so. The same sentiment was shared by several other interviewees that the all the industries in the business ecosystem and especially construction sector are quite traditional and well entrenched in their modes of conduct, which causes the renewal to be relatively gradual process that is better measured in decades than years.

The pace of change could perhaps be accelerated by monetary incentives. Interviewee C5 played with the idea of granting a monetary subsidy, if for example deconstruction and recycling was designed and implemented to the building already before the construction stage. Interviewee O6 reminded that such decisions are complicated to accomplish, as they would have to come from governmental level.

Another important aspect to drive the change is the education of future professionals to increase the awareness of circular economy and how they can influence the market and processes with their own actions. Yet, interviewee O2 pointed out that the interested students are often forced to go trainee positions around traditional organizations, where the students end up forming their networks and careers, which forms a sort of positive feedback loop that hinders circular economy from progressing.

Although digitalization was often described as critical to streamline processes, few could elaborate how it could contribute to reusing timber. On the contrary, interviewee O3 regarded digitalization as unessential and possibly counter-productive to progress reuse of timber, since new technological costs would just increase costs. O3 argued that timber is cheap material, which condition is already straightforward to scan, making the benefits of digital solutions negligible. Nonetheless, several interviewees thought that digitalization could help with information management and logistics. Digital services can also help to educate organizations about material efficiency, as interviewee O5 explained that their organization has helped to create self-evaluation tools regarding the topic.

Digital marketplace and centralization of information was also referred to several times as a measure to support the exchange of reusable components. Some examples of existing marketplaces also came up in discussions, and a prototype web store for reused products was tested by the organization of M3 as an experiment, which reportedly gained some interest from visited customers enough to try and make purchases. However, these marketplaces seem to be still small scale. Again, these kinds of undertakings would require collaboration and mutual understanding between the operators of a marketplace and the owners of waste materials.

Some of the interviewees advocated recycling and reprocessing the waste material over reusing the material due to numerous issues in feasibility. For example, the organization of interviewee E3 offered the service to have crushed waste timber transported abroad, where it is produced into fiberboards. Additionally, they had a pilot in partnership with a local actor to produce fiberboards in Finland. Interviewee M3 also suggested this kind of approach and business model to be more viable in comparison to reusing. Additionally, Finland has some actors that are processing composite products out of waste timber, and Destaclean was one of the most frequently mentioned companies in this context. In any case, interviewee F1 was extremely optimistic about the current research and innovation around wood which is constantly progressing, and it is difficult to predict what kind of new products and innovations are yet to come in the future. These future innovations may also yield new opportunities for reusing C&D timber waste.

The common thread in both the discussed problems and solutions seems to quite often be the communication and collaboration between actors. The key to change could be how to reconstruct the activities within and between the actors of the business ecosystem to make the reusing and recycling of timber profitable proposition. Based on the interviews, any kind of activity or venture around reused C&D waste timber is unlikely to develop without valid and sustainable business.

"It is always good to remember that it's a damn long way from good ideas and research to profitable business. That's a cold fact." - C1 citation

Table 4.9.1. Summary of the most relevant findings about potential solutions that could improve cascading of C&D waste timber in the future.

Dimension	Progress & Reinvention - Insights
M	New actors enabling the reuse of waste timber are needed, although the nature of such actors is still unclear.
M	Pre-demolition auditors could help the material efficiency in buildings' end-of-life.
M	Better networks would enable effective distribution of material streams from waste management.
M	Digital marketplaces could support the exchange of waste materials.
T	Standardization and modularization of construction products and practices can also support reusing materials.
M	Incentives to consider recycling already in design could steer the market to a new direction.
M	Digitalization and better information systems may yield only negligible returns.
S	The education and knowledge-sharing of circular economy practices is important to promote reuse in the future.
T	Recycling might be both more feasible and viable option over reusing waste material.
T=Technological; M=Market/Economic; G=Governmental/Legislations; E=Environmental; B=Behavioral; S= Societal	

5 Discussion

In the discussion chapter, the results from the empirical results are scrutinized in relation to the existing related academic literature by comparing their findings to each other. The aim is to generate cohesive answers to the research questions that have served as the foundation to the discourse of the text. Ultimately, these answers are synthesized to revise and expand on the conceptual framework of business ecosystem around cascading C&D waste timber, so that the framework corresponds to the deeper level of understanding acquired after the analysis of information.

First, the multitude of barriers and inefficiencies opposing cascading and reusing waste timber, as shared by the interviewees, are discussed in the context of the literature around cascading timber and wood construction. This part of discussion aims to answer second and third research questions. Second, a solution-oriented approach is adopted in contemplating the explication of latent approaches to solve the barriers and how these solutions relate and are corroborated by the literature. Thus, answers to the fourth research question are examined in this part. Third, the validity of business ecosystem framework is analyzed and altered accordingly to account for the increased understanding of actors' roles and the intertwining supporting and opposing factors towards more circular lifecycle of C& D waste timber streams. The goal of this part is to provide satisfying answers to the primary research question.

5.1 System Barriers: Inefficiencies and Constraints

The core topic of this paper has been to examine the potential shift from currently prevalent single-stage cascading to multi-stage cascading of timber which is what Vis, Mantau and Allen (2016) also examined from a variety of aspects in their analysis of barriers and promotional measures for cascades of timber in the European Union. Their work sets an excellent premise to inspect the results against to, and compare the congruencies and possible new insights that may also be specific to only Finnish market.

A dichotomic view of cascading timber barriers categorized the identified problems to provision and utilization issues of timber (Vis, Mantau and Allen, 2016). The provision of timber was also found to be a problem regarding the quality of recovered wood to enable cascading timber among the interviewees. Since provision of virgin timber is voluminous in Finland, therefore the price of the material has become low compared to many other net importer countries, which already decreases the viability of changing and developing processes to recover waste timber from demolished buildings in Finland. As such, this sets a huge barrier to reuse C&D waste timber.

Another related barrier comes from the market side, as manufacturers do not have an incentive to design the products to be reusable, as these actors have nothing to gain themselves from such actions (Vis, Mantau and Allen, 2016). This barrier originates from established rules of market economies, where the profitability is determined with maximizing productivity and minimizing costs to harness the economies of scale. Unfortunately, the production of more durable products that incorporated possibility for reuse would result in additional costs and potential losses in sale, which reflects how circular economy and external costs have not yet been assimilated to principles of economics (Braungart, McDonough and Bollinger, 2007; Sauvé, Bernard and Sloan, 2016). Thus, the manufacturers and construction sector cannot be expected to incur costs by investing in research and development, in which the benefits would go to actors later in the product lifecycle.

Furthermore, reusing waste timber for new constructions or other purposes continues to be difficult undertaking because of legislative barriers. In order to reutilize C&D waste timber in constructions, major issues such as requirements of CE-marking and stress grading would have to be solved (Huuhka et al., 2018). Thus, the questions regarding the safety of waste timber remain an unsolved issue. Yet otherwise, legislation has not been considered to directly hinder cascading of C&D waste timber. Pirhonen et al. (2011) also claimed that the legislation of both the EU and Finland is guiding towards recycling instead of constraining it.

The complications to certifications and quality control of C&D waste timber stem from technical barriers. Every step of collecting, sorting, cleaning and applying material to a new usage entail additional costs and labor (Vis, Mantau and Allen, 2016). For this reason, multistage cascading applications are mostly limited to fiber and particle board production, which in case of Finland means exporting the material to other countries for bigger production facilities. Although some other applications have emerged, as new actors have introduced wood composites of different sorts, but the problems with these remains that they would have to be competitive against other material alternatives, which does not always seem to be the case.

The challenge in general from technical outlook is not the infeasibility of the required processes, but finding and accomplishing the optimal configuration of cost management, where the cost of processes is low enough to both be competitive, as in lower price than virgin material, and at the same time be more profitable than selling the material for energy use. Since only particle board production has managed to thrive in some European countries while other business models have failed to reach significant market saturation, this seems to be a particularly difficult formula to accomplish.

All of these barriers contribute to the current practice of delivering the waste timber to energy use and further ingraining its position. Indeed, Pirhonen et al. (2011) confirmed energy production of waste timber to be the best practice currently in Finland and other Nordic countries from both technical and economic point of view, but they also reminded that EU and their waste legislation aims to steer towards recycling. Unfortunately, energy production is no longer included in recycling by the EU, which was also called out to be an unfortunate decision for Finland by one of the interviewees. Thus, next part will explore possible measures to promote reuse and recycling of C&D waste timber.

5.2 Cascading Timber: Potential solutions

Vis, Mantau and Allen (2016) stated that EU countries with abundance of forest resources tend to have less developed measures to utilize waste timber in comparison to countries affected by scarcity of resources such as Italy and the United Kingdom. The interviews with actors and industry experts seemed to confirm the situation and a few even referenced this contrast between countries. Admittedly, this also seems to reflect the situation in Finland. Due to these differences in countries and sectors, no singular mix of measures to promote cascading of waste timber exists (ibid). The implications are that successful implementations of cascading waste timber in many other countries with their different assortment of incentives and barriers are most likely inapplicable to the situation in Finland. Furthermore, no solution would satisfy the whole range of actors in the business ecosystem, so compromises on some front are practically a necessity.

European Union has in recent years began to promote circular economy further in their publications, while the attention towards material reuse and recycling did not receive much attention before (Vis, Mantau and Allen, 2016). However, barely any of the actors reported about having observed any specific legislative actions that would promote reuse of waste material. This would seem to be caused by the preference of policymakers to enact voluntary and directional measures, instead of imposing regulations that could possibly constrain the operations of the actors and affect their competitiveness.

Moreover, consumer awareness about the sustainability aspects of recycled timber was raised as a measure to promote cascading of waste timber (Vis, Mantau and Allen, 2016). However, while some interviewees said that consumers are becoming more aware about sustainability issues, most thought that the deciding factor for consumers tends to be the price which would seem to confirm the argument of consumer preferences by Winder and

Bobar (2016). The problem with non-binding measures would seem to be that they are easily overshadowed by the cost factor.

One of the most prevalent issues that surfaced during many interviews was the lack of an alternative channel or buyer aside from energy plants. The most potential addition to the business ecosystem would seem to be pre-demolition auditors that would give assessments of material in demolition sites. Promising example cases exist in Germany, where demolition auditing has been used to evaluate and compare material value to demolition costs in order to optimize the best solution (Pirhonen et al., 2011). In addition, reusable material dealers have yet been lacking from the ecosystem in Finland (Hradil et al., 2014). Interestingly, Vis, Mantau and Allen (2016) do not recognize the need for either of these actors specifically in their suggested measures to promote timber cascading, but instead recommend development of support networks and bioeconomy clusters. In addition, completely new actors and startups were suggested to disrupt the ecosystem, but no one could elaborate what their value proposition or business model could be.

The major constraint preventing the proliferation of material dealers in the ecosystem seems to be the lack of standardization for C&D waste timber which was also acknowledged by Vis, Mantau and Allen (2016) that recommended harmonized EU standards for waste wood. Implementation of well-structured standardization could be seen as the prerequisite for more efficient sorting of waste material, and it could also indirectly encourage actors to improve demolition and deconstruction processes, so that the material could be graded higher and thus receive a better price.

Since another doubt of the feasibility of reusing waste timber has been the uncertainty of constant supply, the increased wood construction could naturally produce more timber to be cascaded in the future. The role of municipalities in promoting wood construction has been established to have prominent part, as they are allowed to require wood construction in zoning. Wood construction and the implicated modular timber elements have also direct benefits towards circular design. Ramage et al. (2016) suggested wood construction to have perks such as decreased cost and amount of waste and faster installations. Another solution to sporadic supply of material could be more sophisticated implementation of information systems and digital communication, which would allow smarter distribution and compounding of different sources of material supply.

Regardless of what the specific measures for cascading timber are; the market, policies and the involved stakeholders have major effect on the end result (Vis, Mantau and Allen, 2016). The next part explores how the composition of the business ecosystem could be affected by drivers set by the market and policymakers.

5.3 Business Ecosystem: from linear to circular

One of the initial questions that should still be raised after assessing the empirical findings is that does an actual business ecosystem exist around the lifecycle of C&D waste timber? However, such contemplations would prove void, since the business ecosystem model should not be considered as an alternative state to industries, sectors or value chains, but instead to provide a mental model allowing to understand the complexity and interconnectivity of actor relationships (Moore, 1993; Peltoniemi, 2004). However, the industries and sectors have been addressed separately throughout to better address different actors in the business ecosystem. While the forest industry and wood product industry was initially separated into their own entities in the conceptual framework, the two are singularly addressed as forest industries in the definitions expanded meaning in the business ecosystem examination to retain clarity and simplicity. The key actors identified by Antikainen et al. (2017) seemed to apply well to the reality about the related actors of the forest industry and the construction sector. Nonetheless, the business ecosystem in this instance refers to the holistic view of all the actors and industries that have stake in the long, but still rather linear lifecycle of timber.

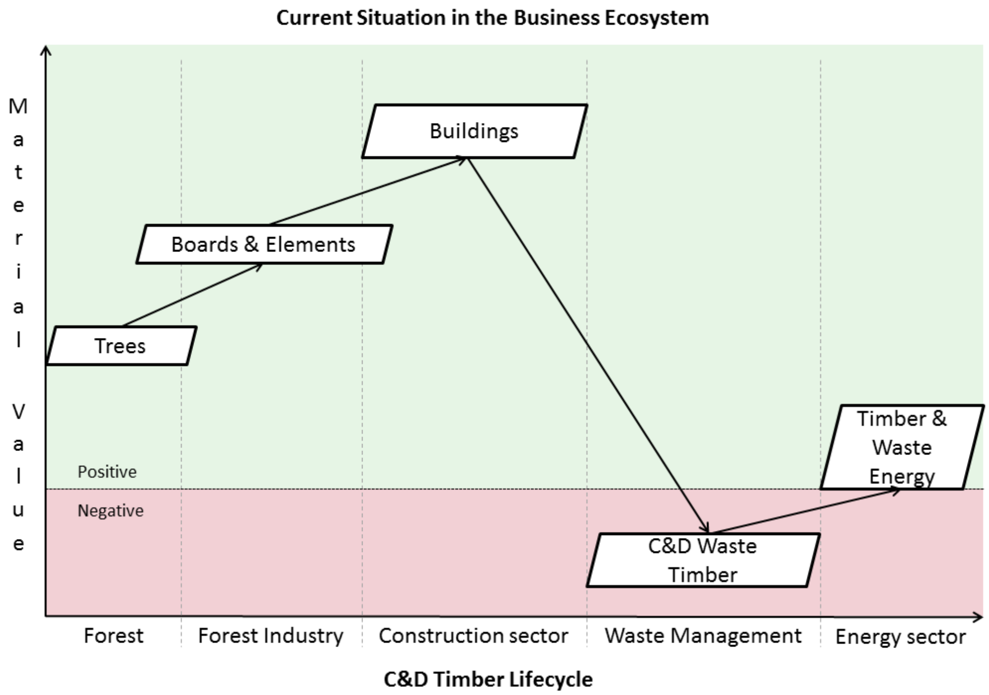
Ergo, the network of actors can be defined as a business ecosystem, but how should the outlined ecosystem be reconfigured to support the reuse and recycling of C&D waste timber further? It is quite evident that all the industries and the ecosystem have ended up in the current situation and adopted the explored widespread activities purely because of cost efficiency and within the boundaries of regulations. Hence, the previously identified and validated constraints forge the shape of potential interactions between actors.

Major problem to actually improve on material efficiency and reuse is the existence of too many different actors with conflicting interests (Korhonen, 2004). Thus, one strategy to recreate the business ecosystem option would be backcasting (ibid), which would allow ignore some of the conflicts and constraints, such as the cost efficiency of reusing timber, which would be regardless difficult to assess on a theoretical level. For example, the strong competition and weak relationships between waste management actors in Finland could prevent deeper collaboration to find higher value for waste streams.

The influence and impact of the actors was already discussed several times in the results, but power and control seemed to be shared to some extent by all the stakeholders. Hradil et al. (2014) found building owners and investors to have an equally crucial role as designers in reusing projects. Interviewees shared similar opinions, although for example an architect considered their profession to have somewhat lower influence compared to experiences in another country. Construction contractors seemed to have lower control in a sense, but their established processes in themselves could be seen to guide construction industry to certain material choices, namely concrete. The municipalities were often cited to have a key role in construction sector with zoning and construction inspection. Waste management industry has a few bigger actors that compete over the clients and material, which is also reflected in the power struggle over waste legislation which could benefit some actors over others.

The major dilemma to harnessing circular economy to reality would still seem to be the dichotomy between designers with their visions for sustainable solutions and market-oriented ecosystem (Pomponi and Moncaster, 2017). Hence, these two major intertwining issues impede the progress of cascading waste timber in the business ecosystem for which two primary measures are suggested; first, the emergence missing actors of pre-demolition auditors and material dealers, and second, the implementation of circular design. The pre-demolition auditors and dealers could redirect the waste timber material stream to cascading use from construction and demolition sites already in the short-term time span. The dealers could alternatively be substituted with a marketplace platform, but this would require contribution from various actors to participate in in order to utilize the network effect, which may require even greater change of the ecosystem dynamics. Integration of circular design to timber products, elements and buildings would contribute to the multi-cascading of material in the long-term, once these circular design buildings would reach their end-of-life status.

Figure 5.3.1. illustrates the reconfigured business ecosystem that has been augmented for cascading C&D timber. Since circular design is unlikely to be adopted by market mechanisms; governing imperatives and requirements from municipalities should require the implementation of circular design with modularized elements that are easy to disassemble and deconstruct. The primary purpose of the circular design is to pre-emptively reduce the amount of generating C&D waste timber, as material that has been used once would be reutilized directly to a new location. Additionally, circular design could help to shift the mindset from considering buildings as final destination to temporary material storage. Pre-demolition auditors and material dealers in the end of the lifecycle help to retain the value of material and bring material back to earlier stages with the help of standardized grading of waste timber. De Wit et al. (2018) also suggest that the most relevant strategies for circular economy in housing are design for the future and collaboration to create joint value.



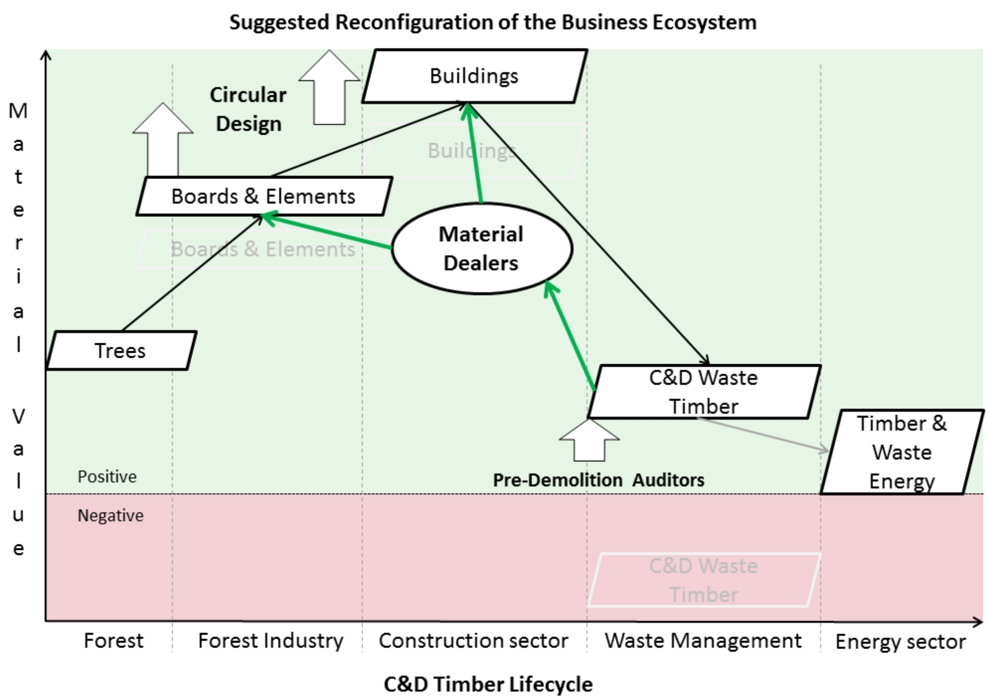


Figure 5.3.1. An updated conceptual framework and suggested measures to promote cascading C&D timber. The upper illustration represents the current situation, while the lower illustration shows the suggested reconfiguration.

However, such changes to the business ecosystem would most likely have multiple evident and unforeseeable consequences to the industries and the actors. Circular design would increase development and production costs both in the manufacturing companies and the construction sector and also possibly decrease sales of manufacturing companies further in the future. New construction methods could increase the risk of faults in buildings that would further increase costs and be against the environmental sustainability principles, if a building has to be deconstructed or demolished earlier than intended. The reuse of C&D waste timber material in buildings would complicate logistics. Unless the quality control is strict enough, the reused material could introduce health problems and possible defects to new buildings. Energy plants would have to replace their fuel material with something else other than waste, which would most likely mean virgin material and render the environmental benefits of material reusing to nonexistent, if not even contributing to additional carbon burden to atmosphere. Whether or not such an alteration of business ecosystem would yield economic and environmental benefits or losses is uncertain. One of the major lessons of the business ecosystem analysis is the understanding that every action carries multiple consequences. Sometimes even subtle changes can cause unexpected outcomes.

6 Conclusion

The conclusion summarizes the key points and structure of the thesis study. Managerial implications examine how the findings can be applied to actions in the field. Limitations and suggested further research explore what aspects could be explored deeper.

6.1 Research Summary

Finland is facing increasing pressure to meet the Waste Framework Directive by European Union which has set a goal to 70% of construction and demolition waste to be recycled and reused by the year 2020. So far Finland has been unable to reach the goal and one of the cited main contributors to the poor results has been the low rate of reusing and recycling C&D waste timber. Majority of C&D waste timber is utilized for energy recovery, but since the European Union does not include energy use to their definition of recycling, Finland is required to find new ways to utilize their constantly generating waste timber material for purposes that fulfill the definition of reuse or recycling.

The primary objective of the study is to reimagine a new structure for the business ecosystem that diminishes the effects of identified barriers. Thus, the primary research question was how should business ecosystem consisting of the forest industry, construction and waste management sectors in Finland be restructured to mitigate the current barriers for cascading C&D waste timber? The purpose of the secondary research questions was to identify the current situation, barriers and potential alleviation measures. The first supporting research question was: What are the barriers for more efficient cascading of C&D waste timber? The second supporting research question was: Why are the relevant actors related to C&D waste timber using their current practices? The third supporting research question was: How could the lifecycle of C&D waste timber be extended from its primary use?

Business ecosystem concept is applied as the main conceptual framework to provide the economic aspect to the study. The business ecosystem theoretic framework leans on the works of Moore (1993) and Iansiti and Levien (2004). In addition, circular economy principles are adopted from the circular economy research framework for built environment by Pomponi and Moncaster (2017). As such, two conceptual constructs of business ecosystem and circular economy with its sub-construct of waste hierarchy are assimilated to generate an understanding of the ideas in relation to the topic. The resulting conceptual framework views the issue of reusing waste timber from three barrier categories of economic, technical and legislative.

The empirical research of the study consists of industry expert interviews. 21 interviews were conducted in total. The selected sample of interviewees aims to reflect the business ecosystem and the organizations operating within. Thus, four to five interviewees share their viewpoints per each network layers of the forest industry, construction sector and waste management industry. In addition, an expanded outsider view are offered by seven experts related to the business ecosystem, which include specialists from research organizations, material efficiency consultants, and officials from a municipality and an administrative organ of the government. The focus of the semi-structured interviews is the overall situation of the business ecosystem, the technical, economic and legislative barriers against cascading C&D waste timber, and exploring possible measures to enable cascading of C&D timber waste.

The results of interviews adduce numerous traits of actors and barriers against reusing and recycling of C&D waste timber. These are embedded to produce more significant categories and elucidate bigger trends. The main findings are that profitability and cost efficiency has led the business ecosystem to choose energy use as the primary end-of-life destination immediately after the primary use of C&D timber. Technical barriers exist, but they were perceived to be an extension of the economic constraints. Lack of standardization for C&D waste timber and the requirement of CE marking and possible stress grading are major barriers for reuse in the original purpose of material. Designers, building owners and developers are some of the key actors possessing power and influence to both hinder and promote timber cascading. Municipalities and governing bodies have the power to make decisions that either favor or hurt wood construction and cascading of C&D waste timber.

The conceptualization of the reconfigured business ecosystem would introduce two major changes: one to the earlier stage of timber lifecycle in the forest industry and construction sector and second to the waste management. The first measure is to enforce circular design and design for deconstruction principles. The positive outcomes of this measure will become apparent only in the future as new circular buildings would eventually be deconstructed. As no economic interest to integrate design for deconstruction exists, the change would have to be administered by policymakers on European Union, national governing bodies and municipal level. The second measure is to promote the emergence of pre-demolition auditors and waste material dealers to the ecosystem in between the construction sector and the waste management industry, which would assess the quality of material and explore new networks of purchasers for the material stream. Official standardization on EU level of reusable C&D timber material would encourage and assist these activities. However, the accumulation of direct and indirect effects to the business ecosystem of either of these two measures remains uncertain. Figure 6.1.1. summarizes the suggested reconfiguration of the business ecosystem in a more visual format.

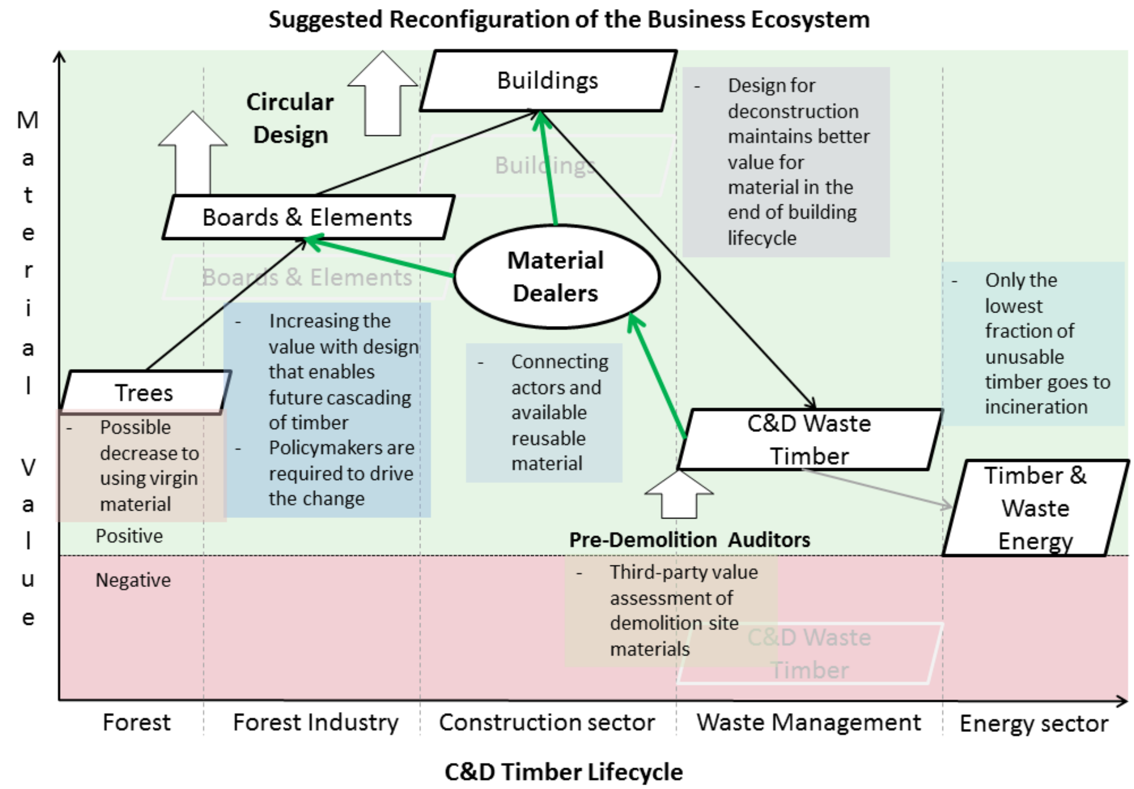


Figure 6.1.1. An updated conceptual framework with further elaboration of the suggested reconfiguration.

6.2 Managerial Implications

The results of this study provide an overall composition of the business ecosystem and actors in the forest industry, construction sector and waste management industry in Finland. The conceptual framework of the business ecosystem helps to illustrate the roles and relationships of all the actors and how the exchange of material between them flows. The framework and insights of industry experts can be used to identify untapped potential and improvements to the business ecosystem. Some of these use cases could be to assess the potential and viability of business models for new actors or old actors redefining their value proposition and services in the business ecosystem around the lifecycle of C&D timber.

Earlier studies and the results presented in here suggest strongly that the trend of sustainable development is growing and policymakers in Europe are supporting the principles of circular economy. Thus, companies within the ecosystem of the three industries should proactively seek ways to align their business operations with promoted measures of policymakers to attain competitive advantage. For example, actors in the construction sector should implement design for deconstruction in their buildings to provide additional long-term value to their clients. Demolition and waste management actors should consider expanding their operations and market either by providing new services such pre-demolition audits or broker material for reuse or recycling either by themselves or by forming strategic alliances with new actors. Overall, managers should be on the lookout for potential collaborations both within and across sectors and also prepare for the emergence of startups with new kind of operating models.

6.3 Limitations & Suggested Further Research

The scope of business ecosystem framework was limited to the three overlapping sectors of the forest industry, construction sector and the waste management industry. As such, the reuse and recycling possibilities were mostly narrowed to analyze possible approaches inside this business ecosystem. Further research could expand to investigate how the currently defined business ecosystem could extend to other potential industries. The results of study conform mostly to the research and findings conducted previously in literature. However, the results help to deepen the understanding by providing viewpoints of all the actors involved along the lifecycle of C&D timber.

As the analytical framework of the research was business ecosystem, the inspection of the conditions around cascading C&D waste timber in Finland have also been skewed towards more economic view in examining the issues. However, it could be reasonably argued that the whole lifecycle of timber is subjected to the needs and constraints of the market.

Unfortunately, as of yet business around reuse and recycling C&D waste timber is still miniscule in Finland.

The business ecosystem framework helped to identify the factors that have the biggest impact according to the actors themselves. Thus, the results represent mostly issues that have an effect directly and specifically on the actors and exactly the pool of interviewees selected as the research sample. Multitude of barriers affecting cascading C&D waste timber and potential measures to overcome them have been identified here, but there could be numerous other barriers that affect the actors indirectly or that actors are otherwise unable to perceive some factors to contribute against cascading timber. Hence, the business ecosystem could be researched more from the viewpoint of actors that were now lacking, such as building owners, residents, developers, contractors or demolition companies just to name a few. Additionally, some completely other entities outside the identified business ecosystem could be explored.

Since the scope of the research was narrowed down to examine cascading of C&D waste timber, a similar analysis of other C&D material streams such as concrete and metals would be interesting to explore and compare the differences between materials. Likewise, the business ecosystem framework could be applied to entirely different industries to explore barriers and potential measures for more efficient business ecosystem. If and when examples of pre-demolition auditing and design for deconstructions appear in the market, the effects and functionality of these activities could be explored to cascading C&D waste timber and how the rest of the business ecosystem has reacted to these changes. Furthermore, the environmental impact of reusing C&D timber waste could be analyzed in the future, since previous research found energy use to be the best alternative in comparison to current recycling options.

The amount of research about circular economy and its applications continues to expand. Studies about material lifecycle analysis and similar environmental and technical research often tends to overlook the economic realities and market mechanisms that often turn out to be the root causes of determining the length of material lifecycles. Author hopes that this thesis helps to raise awareness of the multifaceted motivations molding business ecosystems.

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Appendix

Interview Template Questions

Opening script:

"This semi-structured interview is part of an empirical research for my Master's thesis titled "The practices and barriers for cascading solid timber: Business Ecosystem in Finland." The interviewees consist of various actors within business ecosystem for potential timber cascading. The interview will last about 45 minutes to one hour. With your permission, the audio of this interview will be recorded and the interviewer will also take additional notes during the interview. Do you have any questions before we start?"

Warm-up questions

- Could you introduce yourself and your organization?
- How is your organization involved with timber? What is its role and importance?
- Do you have any previous experiences or sentiments about cascading timber? If yes, what kind of?

General situation regarding the business ecosystem for cascading timber

- Could you describe the current environment in the business ecosystem?
- Who / what are the most important actors involved in the business environment, and what are their roles?
- How involved are you with other actors in the supply chain?
- How is the relationship between the organization and the industry?
- Which actors' collaboration would you need the most to be able to reuse timber? Why?
- Where do you see that your organization and the industry will be in five years from now in terms of cascading timber?

Technical aspects

- How feasible do you consider applying cascading timber practices for your organization in the future?
- What would be the technical constraints preventing your organization from reusing timber?
- What technical factors would enable your organization to reuse timber?
- How important do you see digitalization and its role to enable cascading timber?

Policies & Legislation, restricting or supporting

- How is your organization responding/reacting to EU waste management policies and targets?
- What is your opinion of the current policies for waste and material reuse? In your view, how do the current policies restrict and/or support reuse?
- What kind of policies would encourage your organization to adopt timber cascading practices?

Viability of cascading timber

- What would make cascading timber more attractive and profitable in general
- What are the requirements to make cascading timber profitable for your organization?
- How would the competencies need to be developed in your organization and industry to make cascading timber viable?

Ending the interview

- Is there still something that you would like to share or would be useful for me to know?
- What would you like to know from other actors?