TOWARDS A BROADER USE OF WOODEN CONSTRUCTION MATERIALS: INTERMEDIARY ORGANISATIONS IN THE SUSTAINABILITY TRANSITION OF THE CONSTRUCTION SECTOR

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ABSTRACT:

Aim: This paper presents an ongoing study on sustainability transitions in the Norwegian construction sector, with a focus on increasing the use of wood. The construction sector is very conservative and path dependent. Existing path-dependencies and lock-mechanisms are interrelated and reinforce each other, contributing to an unsustainable development within the sector and preventing a sustainable transformation. These interacting lock-ins create social problems, such as the lack of affordable city dwellings, a high cost for energy efficiency and renovation measures, and less flexibility for adapting dwelling spaces to new needs. A crucial question is therefore how to change path-dependencies and overcome these interacting lock-ins by developing new pathways – what types of actors and efforts are required for such a change? In this paper, we pay attention to the specific role of different types of intermediary organisations in the transition to a more sustainable construction sector in Norway. We investigate how such intermediaries contribute to more sustainable pathways in the construction sector, with a focus on the use of wood.

Method: We apply a mixed methods approach, combining media analysis, interviews, and document analysis.

Findings: We find that intermediary organisations have been very active in the development of new pathways. This applies especially to cluster organisations, which have a clear aim of increasing the use of wood in the construction sector, but also intermediaries taking a more 'neutral' role concerning choice of materials, provide innovation arenas for experimenting with sustainable material use and architectures. We identified technological, institutional, and behavioural path dependencies and barriers for sustainable development. Correspondingly, we discuss new pathways for more sustainable and wood-based constructions and the role of intermediaries in shaping these new pathways.

Conclusions: Development and deployment of new technologies for wood construction need to be accompanied by changes in institutional conditions and in social practices of dwelling. Intermediaries need to broaden their horizon and networks when lobbying for new wood-based solutions addressing such social problems. Intermediaries evolve over time and get new roles, while older roles are taken over by other actors. Different types of intermediaries need to cooperate, have different roles, and interact with other actors in the innovation system.

KEYWORDS: Wooden construction, Intermediary organisations, Norway, Sustainability transition, Path creation, Path dependence

1 INTRODUCTION

This paper presents a study on the innovative use of wood in the Norwegian construction sector to facilitate a sustainable transition of the sector. The construction sector has a considerable economic and social importance, as well as major environmental impacts. Furthermore, it is very conservative and path-dependent, but also rather diverse, encompassing not only the entrepreneurs who are constructing buildings, but also those actors who order the construction, as well as architects, consultants, producers of construction materials, etc. Sustainability transitions must overcome path-dependencies.

Existing path-dependencies contribute to unsustainable development within the construction sector and prevent a sustainable transformation of the sector. A crucial question is therefore how we can change path-dependencies and barriers to enable sustainable development in the construction sector: what kind of new pathways have emerged and what types of actors are required for such a change? In this paper, we pay attention to the specific role of different types of intermediary

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organisations in the transition to a more sustainable construction sector in Norway. We investigate how such actors work to facilitate the increased use of wood-based materials within the sector.

The research questions for this paper are therefore:

- Which new pathways have emerged for a more sustainable construction and building sector based on the use of wood?
- What is the role of different types of intermediary organisations in shaping these new pathways?
- How do intermediary organisations generate new users and markets for wood-based construction materials?

2 BACKGROUND

The construction sector has a considerable economic and social importance, as well as major environmental impacts. If we include the whole lifecycle of buildings, the global construction and building sector stands for 42% of total energy consumption, 35% of total greenhouse gas emissions, 50% of extracted materials and 30% of water consumption [1, 2]. Therefore, improving the resource efficiency and sustainability in the building sector has become an important climate policy goal in the EU and in the Nordic countries [3-7].

As one possible solution it has been suggested to use more wooden construction materials. Wood is a renewable material and has a considerably lower carbon footprint compared to steel and concrete. Studies on the mitigation potential of wood use in buildings and furnishing have shown that wood products have lower greenhouse gas emissions than alternatives over the complete life cycle of the product [8]. There is plenty of evidence supporting the substitution effects [9, 10], but this is still a niche market. Another problem is the large amount of waste generated in the construction and building sector. This includes the construction of new houses, the rehabilitation of buildings and the demolition of existing buildings and other constructions. Construction and demolition waste (CDW) accounts for more than a third of all waste generated in the European Union (Source: Eurostat)[6] and for 29 per cent in Norway (Source: SSB)[7]. Over the last 17 years, there has been a steady increase of waste generated in this sector in Norway: from 1.2 million ton in 2004, to 2.1 million ton in 2020 (data: SSB). Here, demolition waste stands for 46 per cent, rehabilitation of buildings for 24 per cent and new constructions for 30 per cent [11].[8] The highest shares belong to bricks and concrete: 0.6 million ton in 2004 and 0.87 million ton in 2020 (SSB).[9] Wood waste has increased as well: from 0.22 million ton in 2004 to 0.27 million ton in 2020 (ibid.). In addition, there are contaminated resources, which have increased as well.

In Norway, the use of wood as a construction material has dominated the marked for cottages in the countryside and, only to some extent, for houses with no more than two storeys. Normally, houses in the cities are multi-storied and mostly built in concrete and steel. This means that the challenges regarding high energy consumption, GHG emissions, use of extracted materials, water consumption, and waste generation, dominate in this sector.

In the literature, researchers have distinguished between six types of barriers for the extensive use of timber as a structural material for multifamily and non-residential buildings: “code implementation, technology transfer, costs, material durability and other technical aspects, culture of the industry and material availability” [12].

While the literature about the sustainability transition of the construction sector in general is targeting low-energy or passive houses [13], the literature on the wood construction industry has been mainly technical, focusing on quality of construction materials and assembling techniques [i.e., 10, 14, 15] or on specific projects and there used materials and assembling techniques [16]. Recently, there has been more research on the functions of technological innovation systems for wood-frame multi-storey construction [17].

3 THEORETICAL FRAMEWORK

The theoretical framework for this paper consists of three main conceptual building blocks: 1) path-dependence and lock-ins, 2) path creation for sustainability transitions, and 3) the role of intermediaries in sustainability transitions.

Path dependencies can be described as the ways in which a sector, here the construction sector, is ‘locked-into’ certain patterns due to historical developments [18]. Path dependency is not inherently negative, but when the chosen path turns out to be a hinder for new, more effective, and environmentally friendly solutions, those lock-ins function as a barrier for sustainable transitions. Such developments are, therefore, path dependent. Path dependencies are realised through lock-in mechanisms. The discussion of lock-in mechanisms in this paper is motivated by our interest in transition processes and their key barriers. We focus especially on transitions towards a more sustainable construction sector.

We can distinguish between *three groups of lock-in mechanisms:*

- Technological and infrastructural lock-ins,
- institutional lock-is, and
- behavioural patterns and shared social practices of everyday life.

All three types coevolve and are interdependent [19].

[6] https://ec.europa.eu/environment/topics/waste-and-recycling/construction-and-demolition-waste_en
[7] https://www.ssb.no/natur-og-miljo/avfall/statistikk/avfallsregnskapet
[8] https://www.ssb.no/natur-og-miljo/avfall/statistikk/avfall-fra-byggeaktivitet
[9] https://www.ssb.no/statbank/table/09247/tableViewLayout1/

The scientific discourse about lock-ins was originally mostly about technology-related lock-ins, and first later, institutional and behavioural lock-ins came on the agenda.

Technological lock-ins can be defined as positive feedbacks or increasing returns to the adoption of a selected technology [20-22]. Positive feedback mechanisms decrease production costs and create additional benefits for users. The costs and performance of a new technology are more uncertain compared to incumbent technologies [23].

High costs of supporting infrastructure can also contribute to a technological lock-in because it is a barrier to change. Infrastructure is often used for encompassing the communicative system, including transport or distributive systems, like the systems for producing and distributing heat, water, and electricity. Infrastructure systems are special types of societal systems that include the physical artefacts and the institutions, which regulate and manage these systems [24]. With Freeman, we argue that any larger built environments are long-lived fixed assets that can constrain investments in the deployment of new solutions [25].

A stable incumbent regime is the outcome of various lock-in processes, and it favours incremental as opposed to radical innovation. As a result, incumbent technologies have a distinct advantage over new entrants, not because they are necessarily better, but because they are more widely used and diffused. The concept of lock-ins has been extensively used to explain the persistence of fossil fuel-based technological systems, even though their well-known environmental externalities contribute to climate change. Moreover, this 'carbon lock-in' inhibits the diffusion and adoption of carbon-saving technologies [21, 24]. In this regard, initially "minor changes and marginal developments may evolve into massive structural configurations that then restrict the variety of directions to future changes" [26:13].

What are the differences between *institutional and technological lock-ins*? Seto et al. [19] have discussed these differences: (1) Institutional lock-ins are intended and coordinated efforts. They are *not* early chance events like technological lock-ins. (2) Those who enforce these institutional lock-ins profit from them, while others do not. (3) Institutional lock-ins "occur more often and with greater intensity than technological lock-in[s]" (p. 433). However, both institutional lock-ins and technological lock-ins contribute to a trajectory that is resistant to change and that creates increasingly costly and challenging barriers to switching to any alternative trajectory.

Social practices of everyday life can be understood as configurations of meanings, skills, and material objects [27]. Meanings are here referred to as shared understandings and purposes guiding a practice. Skills are forms of routinised, embodied know-how and competence. The material dimension highlights the importance of material objects and infrastructures, which significantly shape the possibilities of practices to change over time [28]. These three elements of social practice can act as lock-ins for change. The social practice of dwelling, for instance, encompasses the material dimension of dwelling, including houses, flats, streets, towns, etc. Meanings include social norms for what is understood as a good and preferred form of dwelling, for example a single house with an individual garden, a shared house, or a flat in a multi-storey building. Skills can encompass maintenance skills, competence for energy efficient living etc. The different social practice fields, such as dwelling, mobility, eating and working, interact and form bundles of practices which can also act as lock-ins [28].

So, how can we overcome path dependence and lock-ins? The concept of *path creation* has gained special relevance in analyses of sustainability transitions [29]. Path creation has been used as a concept to examine how new and more sustainable niches may overcome incumbent systems, and in this way contribute to a sustainability transition [30]. With Simmie [30], we distinguish between the initial conditions of path dependence and ongoing path-creation experiments by different niche actors, planned actions and new path establishment processes to achieve critical mass, key path creation barriers, and envisioned outcomes.

Research on path-creation processes highlights that engaged and entrepreneurial actors are central to technological and societal change [31]. Typically, through long-lasting efforts and interaction between many actors, new paths of development are created which move beyond existing path dependencies. One type of such engaged actors operating in niches are intermediary organisations. The role of different *intermediary organisations* in sustainability transitions has been in focus recently [32-36], and has been proposed as central in accelerating sustainability transitions [32]. A key issue relating to the activities of intermediaries is their survivability and the source and long-term stability of their funding [36]. Kivimaa, Boon [32] define transition intermediaries as:

> "…actors and platforms that positively influence sustainability transition processes by linking actors and activities, and their related skills and resources, or by connecting transition visions and demands of networks of actors with existing regimes in order to create momentum for socio-technical system change, to create new collaborations within and across niche technologies, ideas and markets, and to disrupt dominant unsustainable socio-technical configurations" [32].

Intermediaries can be classified according to their visions, sources of funding, scope of activities, and intended targets (short-term vs. long-term, actor level or system-level outcomes) [37]. We can also distinguish between systemic-, regime-based-, niche-, process-, and user intermediaries [32]. Systemic intermediaries have different functions, such as using and interacting, network building, brokerage, consensus building, long-term strategy development, and creating conditions for learning by doing [38-40].

In this paper we apply the classification developed by Kivimaa, Boon [32], and applied by Vihemäki, Toppinen [41] who investigated the role of intermediaries in the diffusion of wooden construction of multi-storey buildings. They point out that intermediaries are able

> "to work across the often-impermeable boundaries between different actor groups, arenas of action, or geographical scales. Intermediaries are seen to play an important role in connecting actors in situations in which direct interaction is challenging because of high transaction costs, communication challenges and information asymmetries" [41].

4 METHOD AND DATA

We apply a mixed methods approach, combining media analysis, interviews, and document analysis. The media analysis is based on the retrieval of all printed newspaper and magazine articles (national, regional, local, trade press and magazines) published in Norway on wooden construction between 2011 and 2021. The data source is Retriever, the leading media monitoring company in Northern Europe. We applied a keyword approach and downloaded all the articles. Following keywords were used in the search: *(wood-based OR wooden) AND (buildings OR construction*)*
This covers both wooden buildings and constructions, but also wooden construction materials.

We read all the articles retrieved from the search. Furthermore, all the relevant articles were registered in an event database, containing all the necessary bibliographic information and the thematic focus of the articles. We distinguished between unique events to avoid double counting: some articles have been published in several newspapers, either with the same or similar titles. They were identified and in the final analysis they were only considered once, to avoid artificially high numbers. We registered 179 unique articles out of 235 articles. The media analysis also informed the other steps of the analysis, such as the selection of interviewees and the selection of commissioned reports and policy documents. The next step was to gain a broader insight through interviews with different actors identified in the media analysis and via the snowballing technique among interviewees. We created an interview guide and conducted 20 interviews (see Table 1).

Table 1: *Interviews (N=20)*

Type of organisation	Number of interviews
Private intermediaries	7
Cluster organisations	4
Systemic intermediaries	2
Niche project	1
Public agencies, ministries	6

The interviews lasted for about an hour, were conducted online and were recorded and transcribed afterwards. The interviews were analysed with NVivo, a qualitative data analysis software. Document analyses of important commissioned reports and policy documents, highlighted in the media analysis and during the interviews, completed the empirical background of the study. These documents were included in the NVivo analysis as well. As a result, we created a narrative addressing the research questions. Here, we concentrated on path dependencies and major obstacles for new developments, new pathways for more sustainable and wood-based construction, and not least the role played by intermediaries in shaping these pathways.

5 FINDINGS

Based on the media analysis, a timeline was constructed to point out the main developments in the sector. This timeline includes the following elements:

- main companies, important projects, municipalities, and intermediary organisations,
- political events and policy strategies,
- and barriers and challenges.

The development of media coverage since 2001 can be grouped into three periods:

1. 2011–2012: Introduction of policy instruments, but rather limited awareness.
2. 2013–2016: Political lobbying for public procurement of wooden buildings, strategy development, and the start of the first forest-based cluster organisation.
3. 2017–2021: Industrial capacity building, pilot projects and new intermediary organisations.

When analysing the new pathways for a more sustainable construction and building sector based on the use of wood, we need to first identify the existing path dependencies and lock-ins.

5.1 PATH DEPENDENCIES

Path-dependencies in the construction sector concern technology and material infrastructure, including learning effects, use of technology and materials, existing physical building infrastructures, high costs and a lot of waste; as well as institutional lock-ins, such as policy instruments and quality standards for construction; and social practices, such as preferences for living in single houses, lacking flexibility in dwelling solutions and lacking competences about effects of building materials on residents' wellbeing.
We mainly identified the following path dependencies, which function as barriers for new path creation:

Technology and material infrastructure:
The building and construction sector is traditionally dominated by solutions based on concrete, bricks, and steel, and the related skills. The existing physical building infrastructure in larger cities is dominated by multi-storey houses in steel, concrete and bricks, while smaller towns have more 1–2 storey-houses in wood. Many larger dwelling complexes in larger cities need energy efficiency upgrading, such as better insulation of walls, which is rather costly.

The *circular economy* is still not well established in the construction sector in general. Reuse and material recycling of wooden construction material is not well established in normal practice yet. Wood-based waste has mostly been used for energy production. Skills regarding the maintenance and improved energy efficiency of dwellings are outdated. Waste production at the construction site has been the usual practice, also in wood-based construction. Demolition of buildings, instead of maintenance and upgrading, have contributed to more waste. The EU's waste directive, to which Norway is affiliated through the EEA agreement, had as a goal that 70 per cent of the waste from both building and construction activities should be materially recycled by 2020. However, in 2020, only 44 per cent of the waste from construction activity was delivered for material recycling.

Costs of wooden construction materials are not stable, and changes are less predictable: A strong growth in costs for all construction materials as energy has become more expensive due to the war in Ukraine, the Corona pandemic, and supply shortages in Canada and other countries. Access to processed wooden construction material from Norway is limited. The import of the material creates higher transport costs and therefore less sustainable projects.

Documentation: The sustainability effects of modern wooden construction are not well enough documented, and this knowledge is not systematized. Technical solutions for fire, sound, rot prevention, wall coverings etc. need to get prequalified, approved, tested, and documented.

Code implementation: Wood-based construction must engage more in developing industrial standards (see institutional path dependencies). Wooden construction projects often require a longer design phase.

Lack of digitalisation happens often due to limited digital competency in the sector. Here, digitalisation is related to information flow, application of data, input parameters in production, and how one can make use of it. A lack of digitalisation leads to higher operation and maintenance costs because the construction process is less effective, things have to be changed constantly, and learning over time is limited. Today, there are far too many opportunities for the digital chain to be broken and inaccuracies to occur. Building Information Modelling (BIM) is the foundation of digital transformation in the architecture, engineering, and construction industry. The signals that most BIM systems create are too inaccurate for a Computerized Numerical Control machine in a factory to understand and to produce the right goods based on them. Therefore, full digitalisation must start with architects and planners.

Institutions:
Existing policy instruments are not adapted to the need for more sustainable construction, and they do not facilitate the use of wood in construction. Too narrow building regulations favour minimal demands regarding environment and climate. They also focus more on energy requirements and less on GHG emissions of materials. Furthermore, they do not include the operation of a building, as well as all the stages of construction. There are many actors in the wooden construction industry who argue for stricter requirements: The environmental product declaration should include the entire value chain, from the production of raw materials and transport of the raw materials to the actual construction site, the construction process, operation and maintenance, and finally how the building materials can be reused at the end of a building's life.

The *governance of the construction sector* in general and of wooden construction specifically is distributed over many ministries and public agencies, which leads to fragmentation of the political steering. This political fragmentation hampers coordinated strategies and better regulations. All these ministries and agencies issue directives and support schemes, which go in different directions and are often just restricted to a short period. Because there are so many policy actors, this is perceived as very bureaucratic and less impenetrable. Thus(?), policy learning across those different actors is quite impossible.

Public procurement regulations are misinterpreted, and often local administrations do no not favour wooden solutions in their tenders. Competencies in public administration is not updated, and there exist tighter connections with concrete and steel construction.

The *lack of ordering competencies* in municipalities contributes to maintaining established path dependencies. Municipalities are obliged to publish tenders for constructing schools, childcare, or elderly care. There are several municipalities who have developed ambitious climate strategies and link such tenders to these strategies. However, very many municipalities still ignore the new possibilities for sustainable construction because they lack competencies about how to include sustainability requirements for the choice of material in their tenders. Wooden construction solutions were traditionally restricted to 1 or 2 storey-buildings due to fire regulations, with little architectonic innovation.

Behaviour and social practice:
The building and construction sector is very *conservative* and there exist many conflicts. New wood-based solutions must compete with well-established practices in the steel and concrete industry, which also has improved their carbon footprint, instead of combining the most innovative and sustainable solutions from wood, steel, and concrete. Established entrepreneurs mostly favour proved solutions, where they already have collaboration partners and supply chains, and know the costs and the risks.

There are big challenges regarding *construction waste:* Wooden construction waste is commonly used as an energy source – so-called energy recovery – but this is not material recycling. Large amounts of waste come from the established practice of tearing down existing buildings, and building new ones, instead of maintaining, retrofitting, and upgrading existing buildings.

Small and medium-sized enterprises (SMEs) have less of a focus on developing new competencies, collaborate little with higher education and research institutions, do not hire many new candidates with new ideas and competencies, and are not at the forefront regarding the deployment of innovation. The collaboration between SMEs is not well developed because the SMEs are afraid of losing a competitive advantage. Some of the *larger companies* are more active. Often, they do not want to carry the costs of being a fast mover in wooden construction but would rather sit and wait until the costs decline further. The willingness and ability of the Norwegian state and other public builders to *pay the high prices* of construction firms is a part of why these firms are not being forced into become more effective and innovative.
There is a lack of living space in larger cities due to restricted space and due to inflexible dwelling solutions. Large dwellings are not used effectively because elderly people don't want to leave their social environment and alternatives are not offered.

These path dependencies and lock-ins are of course interlinked and reinforce each other: The consequences are high energy and water consumption, high waste generation, GHG emissions, and extended use of extracted materials.

5.2 NEW PATHWAYS

We identified four types of new pathways for more sustainable and wood-based constructions. We distinguish between pathways that are centred on organising sustainable construction processes differently, pathways that lead to more sustainable and innovative wood-based construction technology, pathways for broader market developments, and pathways that are supported by changes in institutions and policy.

New pathways for organising a more *sustainable* construction process:

- *Cooperation of the value chains in the construction process:* The construction process is traditionally divided into three main stages: an early stage which includes planning and designing, the main construction stage, and the operation and maintenance of the building. However, we must also include the other value chains, which ensure the access to the wooden building materials. A closer cooperation between different parts of the value chain is required. This includes the industrial production of wooden construction elements. Moreover, modules from local resources allow much faster and more effective production, with less wooden residues.
- *Transportation:* The reduction of costs concerning transport of construction materials is one of the priorities for the industry. This implies shorter distances from the sawmills to the producers and the factories, but also improved transportation infrastructure, such as forest roads and bridges that allow transportation of larger volumes and access to containers.
- *Sustainability criteria:* The introduction of GHG accounting and Life Cycle Assessments allows builders to identify the key areas for necessary improvements: necessary efficiency gains, transport costs and emissions, waste reduction, as well as reuse and recycling.

New pathways for more sustainable and wood-based construction *technology*:

- *New technologies for timber constructions:* Cross-laminated timber (CLT), often combined with Glued laminated wood (Gulam) is used for building larger wooden constructions which replace steel and concrete solutions. The use of CLT was initially more common through import of material and competence from Austria. Later, own production capacity has been developed, which allows the use of local or regional timber resources, which has also lower GHG emissions.
- *Timber stud partition:* Norway has traditionally used timber stud partition for buildings up to 4 storeys, but now there is a new development: a pilot for using timber stud partition for 8 storeys buildings.
- *Hybrid materials:* Wooden construction elements are combined with other low-carbon construction materials, such as low carbon concrete or steel, recycled aluminium or glass, to deploy wood where it has the most advantageous characteristics, such as low weight and easy add-ons.
- *Retrofitting & superstructures:* Besides constructing new buildings in wood, a new market segment has received attention: (1) retrofitting of existing buildings with the help of prefabricated wooden façade elements, which allows a faster and less costly retrofitting process; (2) construction of wooden superstructures on top of existing apartment buildings and adding a lift house which better utilises the building ground and existing infrastructure in cities.
- *Prefabrication:* By automating the prefabrication processes, the construction process at the building site can be much shorter. Moreover, the working environment at the building site, especially regarding noise and dust, will improve dramatically. Wooden residues minimise, and costs go down.
- *Digitalisation:* A stronger focus on documentation of characteristics of each construction element is essential to facilitate the reuse of construction elements in future disassembly of buildings, which also will allow the reuse of these materials. Moreover, it will benefit from the digitalisation of the whole value chain, from forestry to sawmills, to producers of

construction materials, to the planning and design stage, to the construction process, and finally to the operation and maintenance stage. The use of digital twins allows a much better coordination in these processes.

New pathways for *broader market development:*

- *Niche development from show cases to individual one-off buildings:* In the first years, wooden construction concentrated on interesting show cases, such as the famous buildings for the Winter Olympic games in Lillehammer 1997 or the Gardermoen Airport in Oslo. However, it is difficult to move from huge show cases to a broad deployment of wooden construction, to achieve an upscaling of this niche. Therefore, an important step in that direction was the construction of individual one-off buildings, such as schools, kindergartens, and health care homes, commissioned by municipalities. This allowed entrepreneurs to learn and build collaboration networks. Many of these projects, such as schools etc., had repetitive characteristics, which allowed economic gains and reusing existing solutions.
- *Niche upscaling towards a mass market:* An important pathway has been the construction of residential buildings for students. These were not just one-off buildings, and were based on collaboration with student welfare organisations, which commissioned many buildings, such as in Ås, Trondheim, Fredrikstad and Oslo. A further step has been to move into the private market for industrial buildings in wood, being it office buildings or factories.
- *Cooperation with housing associations:* While the cooperation with municipalities targets the construction of individual one-off buildings, the cooperation with housing associations opens a market for larger volumes. Housing associations often have many buildings which need to be renovated and retrofitted (new facades). Many of the newer buildings have flat roofs, which allow extensions on the roof in light-weight wooden construction. Combined with added lift houses, this allows for building more flats that the elderly people can stay in (due to the new lifts). Moreover, this lowers the costs for the residents.
- *Export market:* The sale of Norwegian wooden construction materials is still concentrated in the domestic market, and the possibilities of the international market are not in focus.

New pathways for more sustainable and wood-based construction regarding *institutions and policy*:

- *Policy instruments:* Three dedicated policy instruments have provided public support for the use of wood in construction: Innovation Norway had a wood innovation programme, which also included co-funding, together with regional authorities of a national network of intermediary experts – so-called *tredrivere* – to facilitate the use of wood. The Ministry of Agriculture and Food has financed subsidies for the construction of wooden farm barns, and the Directorate for Environment has a funding instrument, Klimasats, that is supporting municipal projects in different areas of sustainability transitions. In one period there was a focus on municipal projects using CLT for schools, daily childcare, nursing homes, etc.
- *Public procurement:* The development of competence on public procurement rules in municipalities is essential to facilitate more sustainable solutions.
- *Initiatives for reuse and material recycling:* In 2021, the development of a Circular Resource Centre was started, which operates a National Knowledge Arena for reuse in the construction industry and a warehouse centre for used building materials. While this centre is for the construction industry in general, it has also been necessary to address reuse and material recycling in wood-based building and construction.
- *Regulation and standards:* The regulatory framework conditions for building with wood changed around the year 2000. According to the Planning and Building Act and technical regulations, it was allowed to build higher than three storeys. The technical regulations on the construction side have been focused on steel and concrete construction, both how they are formulated and how they are exercised. What we are seeing now is that sustainability criteria, such a LCA and CO_2 footprints, will be included into technical regulations and standards for construction materials. The European revised construction products regulation will also be effective in Norway when it is approved. This will include an assessment of construction materials regarding sustainability and documentation requirements for reused materials. This will be a driver for using wood as it has a lower footprint than other materials.

5.3 INTERMEDIARY ORGANISATIONS

Intermediary organisations have been very active in the development of these new pathways and in addressing the path dependencies and barriers discussed above. In the following we discuss the roles of different types of intermediaries in shaping the new pathways and how they generate new users and markets for wood-based construction materials. We take the new pathways, discussed above, as a starting point.

New pathways for organising a more sustainable construction process: Here we included issues related to the cooperation of the value chains in the construction process, transportation of materials, and sustainability criteria in the construction sector.
For these issues, two types of intermediaries were very active: systemic intermediaries and industry associations, a type of niche intermediary.

Systemic intermediaries pursue sustainability goals on a systemic level, but they do not belong to the wood construction niche. We could identify systemic intermediaries which take a more 'neutral' role concerning choice of materials, but they provide innovation arenas for experimenting with sustainable material use and architectures. Examples are the Norwegian Green Building Council, a member organisation of the building sector, and the Future Built Programme, owned by municipalities, ministries, and public agencies.

Industry associations: Treindustrien (The wood industry) for example, is an industry association for manufacturers of lumber and other wood-based building materials. This association works towards the national government, regional authorities, municipalities, and other public actors, through lobbyism regarding better framework conditions for wooden construction, improvements of transportation possibilities, and stricter sustainability criteria in technical regulations, standards, etc.

New pathways for more sustainable and wood-based construction technology. Here, we cover new technologies for timber construction, timber stud partition, the use of hybrid materials, retrofitting and superstructures, and automated prefabrication and digitalisation.

Regarding technological pathways, there were especially two types of niche intermediaries that were very active: cluster organisations and private niche intermediaries, in addition to the Wood innovation programme under the regime-actor Innovation Norway.

Niche intermediaries mediate between local projects, and/or at a higher level of aggregation. They are part of, and advance, the wood construction niche. *Cluster organisations*, like WoodWorks!, Norwegian Wood Cluster, and Tre på Agder (Wood in Agder), set clear goals to increase the use of wood in the construction sector and to facilitate the development and deployment of new technologies in their member firms. The cluster organisations also include research institutes, universities, and providers of vocational education and training, which develop new knowledge and a competent work force.

Private niche intermediaries are small companies, such as TreFokus, Trebruk, and Tretorget, who distribute knowledge and competence about new technology to municipalities and entrepreneurs.

New pathways for broader market development: This encompassed niche development from show cases to individual one-off buildings, niche upscaling towards a mass market and cooperation with housing associations.

Here, different types of intermediaries were very active. *Systemic intermediaries*, like Future Built, have made innovative projects more visible so that they can function as show cases.

Many *regime-based intermediaries* contributed to this market development, such as Innovation Norway, the Wood innovation programme and subsidies for the construction of farm barns under the Ministry of Agriculture and Food, and Klimasats under the Directorate for Environment. Public procurement by municipalities and other regional authorities, led to funding of sustainability projects at the municipal or county level. Two types of niche intermediaries have to be highlighted: A network of knowledge mediators financed by Innovation Norway and county authorities who support lobbying activities of an expert in each county for deploying wood, a so-called *Tredriver*. Moreover, the private niche intermediaries were decisive for starting entrepreneurial activities together with student- and housing associations.

The efforts made by these intermediaries have contributed to a better collaboration within and across the wood-based industry, such as between the forestry sector and the wooden construction sector. For example, intermediaries create learning arenas and connect actors by hosting seminars, site visits, field trips—nationally and abroad (e.g., to the Netherlands and Germany) —. as well as dissemination and communication work. They also connect companies with research groups and act as translators by assisting companies in applying for research grants.

New pathways for more sustainable and wood-based construction, regarding institutions and policy: This includes the development of dedicated policy instruments, competence for public procurement, policy for a circular economy, and regulations and standards.

Industry associations like Treindustrien have been active in lobbying for better political framework conditions, including regulations, standards, and support schemes. The network of knowledge mediators and the small private niche intermediaries were mostly active regarding the development of ordering competencies in municipalities for facilitating public procurement of wooden construction projects. Moreover, they contributed to attracting new users to create a demand for wooden construction solutions, and to support competence development—among others by working to change education institutions towards a greater focus on wood-based constructions.

For addressing the circular economy of wooden construction, there has been established a new large green platform project, SirkTre, which targets reuse and recycling of wooden construction materials. In this niche project, the Circular Resource Centre is a member, beside many other players in the sector. One of the goals is to function as a "reverse sawmill" and produce lumber again, from material-recycled wood. Lobbying for supportive policies for reuse and material recycling is a priority.

It is important to point out that, very often, the intermediaries work together: the cluster organisations cooperate with the small private niche intermediaries, the network of experts and the industry associations. Moreover, the intermediaries have close connections to the different actors in the technological innovation system around wooden construction: to knowledge providers, such as research organisations and architecture and engineering consultancies; to education institutions at different levels; to entrepreneurs, who have gained a lot of experience in wooden construction; and to municipalities and other public builders, who have commissioned wooden buildings and can serve as a source of inspiration and competence about how to organise such processes.

6 CONCLUSIONS

The development of wooden construction depends on an interplay between technological innovation and the different actors in the innovation system, contributing to new path creation and overcoming existing path dependencies and lock-ins.

Development and deployment of new technologies for wooden construction needs to be accompanied by changed institutional conditions, regulations which require more sustainable solutions in the construction sector leading to reduced GHG emissions, reduction of waste and energy consumption, and changes in social practices of constructing. This requires competence development in all parts of the innovation system.

We mainly identified the following path dependencies, which function as barriers for new path creation: technology and material infrastructure, institutions, as well as behaviour and social practices. They are interrelated and reinforce each other, and they create social problems, such as lack of affordable dwellings in cities, high costs for energy efficiency and renovation measures, low shares of material reuse and recycling, and less flexibility to adapt dwelling spaces to new needs (for young families or for elderly people).

Intermediaries must address and break up these interlinked path dependencies and barriers for new path development.

Intermediaries evolve over time and get new roles, while older roles are taken over by other actors. Intermediaries need to broaden their horizon when lobbying for new, wood-based solutions, addressing such social problems.

When organising a *more sustainable construction process*, there were especially two types of intermediaries which were very active: systemic intermediaries and industry associations, a type of niche intermediary.

For the development of *more sustainable and wood-based construction technology*, there were especially two types of niche intermediaries which were very active: specialised cluster organisations and private niche intermediaries, in addition to the innovation programme under the regime-actor Innovation Norway.

New pathways for broader market development have been facilitated by systemic intermediaries like Future Built. Regime-based intermediaries nevertheless also contributed to this market development, such as Innovation Norway, the Wood innovation programme, and other programmes, as well as two types of niche intermediaries: a network of experts in each county, a so-called *Tredriver*, and the private niche intermediaries, who have been decisive for starting entrepreneurial activities.

The efforts made by these intermediaries have contributed to a better collaboration within and across the wood-based industry, such as between the forestry sector and the wooden construction sector. It is important to point out that very often the intermediaries work together and that the intermediaries have close connections to the different actors in the technological innovation system around wooden construction.

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