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ARTICLE

Barriers to implementing adaptable housing: architects' perceptions in Finland and Denmark

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Abstract
Adaptability is one key aspect in making housing more sustainable. One major approach to adaptability is internal transformability of buildings, i.e. the possibility to make modifications to the spaces and their equipment within the existing building envelope. This aspect is often taken into consideration in the design and implementation of office buildings. However, in housing the situation is different, and internal transformability is very seldom implemented in apartment buildings. There is a lack of studies for the reasons for this. In this article we take a look at the barriers to internal transformability of apartment buildings in two Nordic countries, Finland and Denmark. We compare the situations in both countries, and highlight their similarities and differences. The research is based on interviews of Finnish and Danish architects who have been involved in designing such buildings within the last 20 years. The interviews show that the disinterest of housing developers has been the main barrier to implementing internal transformability. Another important barrier is the developers' cost-optimization. Secondary barriers were related to lack of solutions in building services that would support internal transformability. Additionally, secondary barriers were related to common construction techniques, regulations, and building conventions. Major barriers were similar in both countries. However, some differences in the secondary and other barriers between the two countries also exist.

Keywords Design for adaptability · Internal flexibility · Transformability · Multifamily housing · Apartment buildings · Obstacles

1 Introduction

Housing is a complex issue with a variety of critical viewpoints pertaining to social, economic and environmental sustainability. While access to housing and housing affordability fall within the first two mentioned types of sustainability, longevity can be regarded as an essential condition for environmentally sustainable housing. In the circular economy, lifecycle extension through reuse and repair is the first principle to be considered before any

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others (Stahel & Reday-Mulvey, 1981). The longer a building stays in service, the smaller are the environmental impacts of its initial construction, the so-called embodied impacts, per year in service. Thanks to recent advances in buildings' energy performance and the decarbonization of energy production, the initial carbon investment into the construction materials is the more significant the more energy efficient the building is (Röck et al., 2020). Thus, the more relevant it becomes that new buildings indeed reach long lives.

Historian Arnold Esch wrote, based on his observations as an antiquarian, that the only buildings surviving over centuries are those adapting to the needs of succeeding generations (Esch, 2011). Steward Brand famously argued that all buildings adapt to some extent, even if most of them are not specially designed for adaptation (Brand, 1994). Others have asserted that buildings should not be judged only against their present state but also their potential to accommodate change (Thomsen & van der Flier, 2011). Design for adaptability can be a means to increase the longevity potential of new buildings as well as buildings to be renovated. Indeed, there are several solid arguments to justify the need for pre-planned adaptability in housing. Many cities are densifying due to rapid urbanization (United Nations, 2019), which creates pressure to increase housing density—also in the existing stock. History has shown that household size and composition evolve over time (e.g. Lankinen & Lönnqvist, 2010). Housing preferences of people also change. Moreover, living and working are becoming more intertwined (Eurostat, 2020) and a strict separation between the two is no longer meaningful. Recent empirical research by Femenias and Geromel (2019) has documented that the need of people to make adjustments to their dwellings is indeed a real phenomenon.

Despite decades of academic critique towards housing production practices, apartment buildings—unlike offices and retail premises—are still not usually built to be adaptable. During the design stage, architects may occasionally introduce concepts that provide adaptability, but successful implementations are rare. There is a lack of understanding for the reasons for this. So, in this paper, we scrutinize the barriers to implementing adaptable housing in two Nordic countries, Finland and Denmark, by interviewing architects in both countries. To give structure to the research, the study is delimited to a specific subcategory of housing adaptability, internal transformability, and its implementation in multifamily housing. The interviewed architects have designed some buildings where this type of adaptability has been implemented successfully. In some of their other projects, the design was originally supposed to be adaptable but the aspect was lost during the design or implementation phase. The purpose is to understand what prevents internal transformability from being incorporated into novel housing projects and, inversely, what are the prerequisites for its realization.

2 Background

2.1 Terminology and main approaches to adaptability

We use the term adaptability to describe a building's potential to change to different uses and requirements. Another term, flexibility, is often applied in the same broad meaning (e.g. De Paris & Lopes, 2017; Gili Galfetti, 1997; Kronenburg, 2007; Schneider & Till, 2007; Živkovic & Jovanovic, 2012). Adaptability usually refers to the use stage of a building. However, the ability to modify spaces during the design stage is occasionally also

interpreted as adaptability (e.g. Gili Galfetti, 1997; Krokfors, 2017; Schneider & Till, 2007).

Adaptability can be approached in many ways and considered in various scales. Most architectural theorists divide the various adaptable solutions into two main groups: firstly, spatial solutions that allow several uses without modifications to space, and secondly, solutions that require transforming the space to adapt it to the new use. Some content themselves with this rough categorization (e.g. Groák, 1992), while others (e.g. Loch, 2011; Priemus, 1969; Tarpio, 2015) define additional main categories and/or add a layer of subcategories (for a review of these, see Tarpio, 2015: pp. 106–107). Nevertheless, these two groups can be understood as the basic principles of adaptability. The principle in which no modifications are required to provide adaptability can be called 'multifunctionality', and the principle which requires modifications may be labelled 'transformability'. There is no consensus on terminology, and authors use different terms for describing the two basic principles (Habraken, 2008; Tarpio, 2015).

Many authors (e.g. Braide, 2019; Deilmann et al., 1970; Leupen, 2006; Thiberg, 1967) divide the solutions based on transformability further into two categories: firstly, solutions that take place inside a spatial unit without affecting its overall size, and secondly, solutions that enable alterations to the unit size. Size alterations can be achieved in many ways. Some of them require downsizing or upsizing the building, others do not affect its volume. Transformable solutions can, therefore, be classified into those that take place inside the building, and into those that modify its perimeter. This dichotomy, too, is recognized by many authors (e.g. Leupen, 2006; Rabeneck et al., 1974; Werner, 1977).

Consequently, adaptable spatial solutions can be classified into three main categories: multifunctionality, internal transformability and external transformability. The current article focuses on the internal transformability of apartment buildings, i.e. transformability that takes place inside the existing building envelope.[1] Multifunctional solutions and those requiring external transformability will not be discussed. Apartment buildings are understood in a broad sense: the study considers all building types where the spaces of at least two different dwellings are located on top of each other.

2.2 Research into adaptability and its barriers

How to design housing to be adaptable has been studied for more than 50 years. Research began in the 1960s (Priemus, 1969; Thiberg, 1967), and was intensive in the 1970s in various countries (e.g. Deilmann et al., 1970; Nilsson et al., 1971; Rabeneck et al., 1973, 1974; Schroeder, 1979; Werner, 1977). Another peak occurred in the 1990s (Cremer, 1992; Gili Galfetti, 1997; Habraken, 1998; Henz & Henz, 1995; Jia, 1994; Priemus, 1993; Tiuri, 1997; van Eldonk & Fassbinder, 1990) and in the 2000s (Krokfors, 2006; Leupen, 2006; Leupen et al., 2005; Schneider & Till, 2007). Research has continued also in the 2010s (e.g. Braide, 2019; Krokfors, 2017; Loch, 2011; Tarpio, 2015) and the 2020s (e.g. Saarimaa & Pelsmakers, 2020). Comprehensive reviews into the manifold aspects of adaptability research can be found in e.g. Schneider and Till (2007), Loch (2011), Tarpio (2015), or Schmidt and Austin (2016).

[1] Please note that some other authors, e.g. Deilmann et al. (1970) and Werner (1977), may use the terms 'internal' and 'external' referring to the boundaries of apartment. In their perspective, changes to apartments sizes are considered external. In this paper, internal and external refer to the boundaries of a building, and all changes inside its boundaries, including apartments size alterations, are considered internal.

A particularly well-known approach to adaptable housing consists of the so-called open building movement, based on the ideas introduced by Habraken (1972) and later developed by many others (Habraken et al., 1976; Vreedenburgh et al., 1990; van der Werf, 1993; Kendall & Teicher, 2000; Geraedts, 2006; Durmisevic, 2006; for the development of the open building movement in the Netherlands, see Bosma et al., 2000). Its main contribution to the adaptability discussion is the principle to divide the building into durable parts over which the occupants have decision-making power together (the 'support'), and changeable parts that the occupants can decide on individually (the 'infill') (see e.g. Kendall & Teicher, 2000).

In all, there is abundant knowledge on how to design and build adaptable housing. There is much less knowledge on why it is not implemented. However, many authors have discussed what enables adaptability, and some have touched upon barriers while discussing the enablers. Barriers can be understood as factors preventing implementation, and enablers as factors enhancing implementation, which makes the concepts intertwined. Heidrich et al. (2017) point out, referring to Bullen and Love's (2011) research on adaptive re-use of buildings, that some non-building related factors, such as owners' and clients' motivation, financial and economic incentives, and legislative frameworks may act as enablers or inhibitors of adaptability. Geraedts et al. (2017) present 17 factors beneficial to adaptability and state that 14 of them increase investment costs. Focusing specifically on housing, Schneider and Till (2005; see also 2007: pp. 35–37, 44) state that in the UK, the obstacles are related to legislation, construction techniques, housing market, culture (adaptability is discussed too narrowly in a limited scope), investment (preconception that built-in flexibility costs more money), and lack of interest and initiative by the building industry. Krokfors (2010), studying Finnish housing, shares many aspects discovered by Schneider and Till, but mentions additionally building culture, housing policy, and cities' policies for urban planning, building inspection, and land sales and rentals as factors that hamper implementing adaptability in housing.

However, many of the authors deal with buildings in general, not housing specifically, and barriers are often covered only indirectly, as the opposites of enablers. Furthermore, the authors focusing on housing consider all types of adaptability, not only internal transformability (the focus of the current article). Moreover, these studies do not seem to have a clear empirical dataset that the findings would arise from. They tend to draw from experience-based theorizing rather than data-driven research, even if the ideas are illustrated with and informed by curated case studies. The previous research also lacks a comparison of the significance of the individual factors identified.

2.3 Housing in Finland and Denmark

The current article investigates architects' perceptions about barriers to implementing internally transformable housing in Finland and Denmark. The two Nordic countries are relatively similar in the numbers of citizens and occupied dwellings (Table 1). The majority of dwellings is located in detached, semi-detached or row houses in both countries. However, the current housing construction focuses on apartment buildings. In 2018, 74% of newly completed dwellings in Finland and 51% in Denmark were apartments (OSF, 2019; Statistics Denmark 2020a).

A major difference is that Denmark is much smaller by area than Finland. Accordingly, its population density is much higher. Despite this, the number of dwellings located in apartment buildings is smaller in Denmark than in Finland. Another difference lies in

Table 1 Key statistics of housing in Finland and Denmark

	Finland	Denmark
Population[a] (1.1.2020)	5,525,292	5,822,763
Land area[b] (km^2)	303,890	42,962
Average population density (inhabitants/km^2)	18.2	135.5
Total number of occupied dwellings (2018)	2,705,499	2,656,933
Occupied dwellings by type[c,d]		
Dwellings in detached, semi-detached and row houses	1,423,121	1,567,001
Dwellings in apartment buildings	1,238,410	1,043,637
Other	43,968	46,295
Occupied dwellings by tenure[d,e]		
Owner-occupied	1,707,990	1,299,583
Rental	900,080	1,349,382
Other (e.g. right of occupancy) or unknown tenure type	97,429	7,968

Source

[a]Nordic Statistics database (2020)

[b]Nordic Co-operation (2020)

[c]Statistics Finland (2020)

[d]Statistics Denmark (2020b)

[e]Rämö/Statistics Finland, personal communication, July 6 (2020)

the tenure of dwellings. Nearly two thirds of Finnish dwellings are owner-occupied but in Denmark, rental housing is more common than owner-occupied. In both countries, the majority of the owner-occupied dwellings is located in detached, semi-detached or row houses (Rämö/Statistics Finland, personal communication, July 6 2020; Statistics Denmark 2020b;). However, owner-occupied apartments are relatively common in Finland but rare in Denmark, as 38% of Finnish apartments but only 12% of Danish apartments are owner-occupied (ibid.).

A special feature of housing in Finland is the so-called limited liability housing company as a form of owner-occupied housing, typical to apartment buildings. In this type of tenure, the dwelling owners are shareholders of a company. The company owns the dwellings and other spaces, and owning certain shares provides a right to use a given dwelling and the common facilities. The shareholders pay a monthly maintenance charge to the company. The rights, obligations and liabilities of the shareholders and the company are defined in general in the Limited Liability Housing Companies Act (Finlex, 2009), and more specifically in the articles of association of the company in question. The companies are usually set up by developers, who sell off all the shares to private individuals before, during and after the construction.

A feature specific to Denmark is the long tradition of organizing housing through non-profit 'social' housing associations. This form of rental housing started in the 19th century, but the vast majority of the housing stock was built after the Second World War, mostly during the 1960s and 1970s. Today, there are nearly 600,000 of these dwellings, i.e. roughly 40% of the rental housing stock is social rental (Landsbyggefonden, 2018). Unlike in many countries, the so-called 'social' housing is available for anyone; it is not specifically directed at people in a precarious socioeconomic position (BL, 2020). Characteristic to the Danish rental social housing is the strong involvement of the residents, as the

associations have boards elected by the residents, which have influence over the management of the estates. There is an intentional societal orientation to provide good and healthy dwellings for ordinary people. The production is subsidized and strictly regulated, but due to its societal mission, it is also development-oriented (see e.g. Kristensen, 2007; Bech Danielsen, 2013).

3 Material and methods

This research was conducted as a focused interview study (Hirsjärvi & Hurme, 2008). To acquire knowledge on the barriers to internal transformability in contemporary housing production of apartment buildings, we approached architects who are known for designing such buildings during this millennium. In our capacity as architects and researchers actively following housing development in our countries, we identified potential interviewees based on our own prior knowledge. In addition, we asked our colleagues working on similar topics to propose relevant names. The interviewees themselves were also asked to name relevant colleagues. Consequently, inquiries were sent to sixteen architects representing different architectural firms, eight in Finland and eight in Denmark. Seven persons accepted to be interviewed in each country. All interviews except one were conducted orally, as one Danish interviewee preferred to answer in writing. The oral interviews were conducted in late 2019 and early 2020. They were recorded and later transcribed.

The interviews in Finland were carried out in Finnish by one interviewer. In Denmark, the interviews were held in English with two interviewers. The presence of the second interviewer, who is a native Danish speaker, enabled the interviewees to use Danish to clarify details when needed. The interviews began with a general discussion on adaptability. Then, the interviewees were requested to discuss their experiences on two kinds of projects: (1) projects where internal transformability was implemented successfully, and (2) projects that were originally supposed to be transformable, but were eventually not implemented as such. As our interest was on the barriers, we found it very important that a discussion about 'unsuccessful' projects and the reasons why internal transformability was eventually stripped from them was also included. Several questions on each topic were preplanned. However, they were followed loosely in the interviews, as emphasis was given to let the interviewees describe their experiences on the projects in detail.

As mentioned in the Background, when adaptability is classified into three general categories, internal transformability is one of those categories. However, in discussing individual building projects with the interviewees, we found it useful to use a more detailed classification of the ideas and solutions applied in order to understand them better. As there is no consensus over the terminology, to enable a precise and informed discussion, a list of common strategies and concepts that can provide internal transformability within apartment buildings (Table 2) was created. The formulation of the list and its classification is our own, but the strategies and concepts included in it have previously been discussed by various authors (e.g. Jia, 1994; Loch, 2011; Schneider & Till, 2007). The list and its terminology were used as a practical tool and a framework in the interviews. As our presumption was that the barriers may differ for different approaches, we found it important to have an in-depth understanding about the approach that was being discussed. So, the interviewees were also requested to make some material about the projects (drawings, renderings, or photographs) available for the interview. In some interviews, to clarify what was being

Table 2 A list of strategies and concepts that can provide internal transformability within apartment buildings

A Possibility to make changes to unit allocation and to unit sizes	B Possibility to make internal transformations to dwellings
A1 (Big) apartments that can be divided to two or more (smaller)	B1 Freedom for the allocation of all spaces (incl. wet spaces)
A2 (Small) apartments that can be joined to make one (bigger)	B2 Wet spaces in a specific zone, others freely
A3 Switchable rooms (or small units) that can be connected to several apartments	B3 Fixed wet spaces, all others freely
A4 Expandable apartments (into attic space, for example)	B4 Fixed wet spaces and kitchen, others freely
A5 (Almost) empty floor areas that can be divided in many ways	B5 Possibility to build loft spaces
A6 Some other strategy	B6 Some other strategy

Table 3 Interviewees

Finland	Denmark
Pia Ilonen, ILO arkkitehdit Oy	*Flemming Frost*, Juul Frost Arkitekter A/S
Esko Kahri, ArkOpen Oy	*Helle Juul*, Juul Frost Arkitekter A/S
Leif Lindegren, Arkkitehdit a-live	*Rolf Kjær*, Arkitema Architects
Jari Lonka, L Arkkitehdit Oy	*Søren Nielsen*, Tegnestuen Vandkunsten A/S
Mari Matomäki, Arkkitehtitoimisto Hedman & Matomäki Oy	*Søren Rasmussen*, ONV arkitekter
Kirsti Sivén, Kirsti Sivén & Asko Takala Arkkitehdit Oy	*Lone Wiggers*, C.F. Møller Architects
Ulpu Tiuri, Arkkitehtitoimisto Tiuri & Lommi Oy	*Casper Østergaard Christensen,* GXN Copenhagen A/S

discussed, the interviewers showed similar material of reference projects that contained concepts which were brought up by the interviewees.

In expert interviews, the quality of the results depends, among other things, on the interviewees actually being experts on the subject (Alastalo et al., 2017). Therefore, publishing the names of the interviewees can be justified (cf. Finnish National Board on Research Integrity TENK, 2019: p. 57). In this study, we offered the interviewees the possibility to remain anonymous. However, all of them gave the permission to publish their name and firm (Table 3). Nevertheless, not to compromise the relationships of the interviewees with their clients, colleagues, authorities, or other stakeholders, we agreed with them that the results are reported so that no single statements are attributed to specific interviewees. For the same reason, it was agreed that no data arising from the interviews will be disclosed.

The interviews were analysed by reading the transcriptions individually and highlighting the parts that dealt with barriers to internal transformability. The mentioned barriers were then described by the researcher and tagged with the initials of the interviewee in question. The written descriptions with initials were later copied into one document, compared, and grouped into general and more precise categories. Consequently, the barriers to internal

transformability could be classified in both countries into three main categories: main, secondary, and other barriers. Main barriers are aspects that appeared in (nearly) all interviews and that were deemed decisive for the inclusion or exclusion of adaptability. Secondary barriers include matters that were brought up approximately in every second interview and barriers that appeared in most of them but were deemed hierarchically inferior to the main barriers. A barrier was considered secondary if it cannot be addressed before the main barrier is resolved. Other barriers encompass matters that came up in the interviews once or twice and that were thus not considered as problematic by most interviewees.

4 Results

4.1 Barriers in Finland

The main barrier identified in the Finnish interviews is developers' disinterest with internal transformability. Secondary barriers relate to prevailing design procedures and fee policies, and building services and construction technology. Many interviewees specifically pointed out that the transformability of building services was neglected in their projects. Other barriers relate to various issues, such as public authorities' interpretations of regulations, urban planning, housing law, and articles of association of limited liability housing companies, among other things.

4.1.1 Main barrier: developers' disinterest

As explained in the Background, in Finland, housing construction in apartment buildings is developer-led. According to the interviewees, housing developers do not regard internal transformability of apartment buildings as a priority. Architects are very seldom asked to provide it. One interviewee explained that they had been involved in a single project in which they were commissioned to design apartments that can be joined together. It had been the only case in the last 20 years that a developer had asked them to consider internal transformability in a housing project. Another interviewee stated:

All of it [the pursuit of adaptability] has come from us, in all our projects.

In the majority of housing projects, the internal transformability aspect is currently neglected. Among the large number and variety of projects in which the interviewees had been involved in, there were only three developer-provided dwelling concepts that entailed internal transformability. These concepts were 'PlusKoti' by Sato in 2005–2013, 'Duo' originally provided by NCC and later by Bonava, and 'Neoloft' by EKE. Two of them (PlusKoti and Neoloft) were first introduced by architects and later adopted by the developers.

Why are developers usually not interested in internal transformability? One reason that often appeared in the interviews is the developers' concern for extra costs. One interviewee had experienced projects where the commissioner did not consider internal transformability as important but still permitted introducing it in the project, given that it does not generate extra costs.

And then when it [the adaptable solution] doesn't cost more, then they [developers] act like, "well, okay let's do it then, as it doesn't cost more".

Another interviewee explained how their original design, awarded in an architectural competition for housing reform arranged in Finland approximately every twenty years, was changed dramatically in the early meetings with the developer. The developer rejected the use of columns and slabs for the structural system right away, and the idea of utilizing access floors in apartments was dropped later, too.

The reason for that was the price. […] We must go for the business-as-usual, and that was an order.

The reason for the reluctance of developers may be that they do not see a financial benefit in internal transformability. Their customers, people looking for owner-occupied dwellings, do not usually ask for it. Two interviewees noted:

Then there's the fact that the developers don't see the economic benefit, because their current products are selling well.

I also wonder […] if the consumer is aware of these options. When the consumer is making choices, have they [adaptability options] been discarded already, for one reason or another? Would there be demand if there was information?

4.1.2 Secondary barrier 1: prevailing design procedures and fee policies

The most obvious secondary barrier to internal transformability is that prevailing design procedures and fee policies in Finland do not encourage it. Introducing internal transformability seems to require architects to take extraordinary roles. Some of them are related to the design of building services, others to e.g. promoting and marketing transformable dwelling concepts.

To implement internal transformability successfully, building services need to be designed to support it. Some interviewees had experienced that building services engineers do not understand the transformability approach well enough. In order to guarantee the transformability features of the project, the architect had to take a guiding role in the design of building services.[2] One interviewee elaborated:

One thing was to explain to the special designer what it [transformability] means. […] You need to be prepared, at this point, that everybody chooses, for example, a walk-in wardrobe, but it may be that [eventually] no one chooses it. You need to provide space to the ducts, so that it can be chosen.[3]

Even when the architects needed not to involve themselves with the design of the building services as actively as in the aforementioned case, many felt that it is important that they consider and sketch at least the main piping routes, especially those related to drainage. One interviewee described the idea to utilize the cavities of hollow-core slabs as a space for bathroom and kitchen drainage, and pointed out that the vertical stacks need to be located very thoughtfully in relation to these cavities. They stated:

The lesson I've learned is that goddammit it's the architect that must think how they, the pipes, run within the structure that is selected.

[2] The Finnish practice is that each designer has a direct contract with the developer. Unlike in e.g. the German model, engineers are not in a subordinate contractual relation to the architect.

[3] Exhaust air vents are required in walk-in wardrobes but may not be necessary in other types of spaces.

As it has been rare for the Finnish housing developers to take a leading role in promoting solutions with internal transformability, the role of the concept promotor has occasionally fallen for the architect. One interviewee found this a major issue:

One of the biggest obstacles is that these projects that deviate from the ordinary need to be driven further by individuals or groups.

The interviewee experienced that the new role is not problematic in itself. The problem is that architects do not get paid for it. The fees for housing design in Finland are very uniform, and they do not encompass compensation for any special tasks, such as concept development for adaptability.

Some very common design objectives also create challenges for introducing internal transformability. In contemporary Finnish housing design, optimizing spaces within apartments according to their specific functions is customary. The shapes and sizes of apartments are considered individually, and usually so that the individual spaces for the required functions and the size of the entire apartment are minimized. An interviewee, who had been involved in designing apartments that can be joined together, noted that in these cases the emphasis cannot be on optimizing the individual apartments, but on apartments as a whole and their combinability:

At no point should you draw an individual apartment, you should always draw the combinable whole. There's a big difference in the fundamental starting point, compared to ordinary housing design.

4.1.3 Secondary barrier 2: building services and construction technology

The other secondary barriers to internal transformability are related foremost, to building services and additionally, to construction technology. The amount of building services has increased in Finnish apartment buildings during this millennium. This is partly due to rising living standards, but mainly due to energy saving regulation. To meet the norms, mechanical ventilation with heat recovery is generally required. Space must be reserved in the building for the equipment pertaining to the ventilation system and for vertical and horizontal ducts. The space they take up varies, depending on whether the system is centralized or distributed. In both cases, a substantial amount of ventilation piping needs to be placed within the apartments. Ventilation ducts run throughout an apartment so that air can be exhausted from bathrooms, kitchens and walk-in wardrobes, and clean air can be supplied to the other rooms. The ducts are usually placed above suspended ceilings, which normally do not cover the whole apartment but only where they are needed to conceal the ducts. Consequently, the room height within the apartment varies.

Many interviewees considered the increased amount of building services equipment, in particular the mechanical ventilation systems, as an obstacle to internal transformability. One interviewee described an apartment building they designed for older adults. In this building, the shape and size of all residential floors are similar but the spaces vary. Some floors contain apartments but others encompass so-called 'group homes' for individuals with special care needs. In the design phase, transformability between the two functions was discussed. However, apartments and group homes require different kind of ventilation. The need to design a ventilation system transformable for both functions was recognized and considered, but eventually it was not realized. The interviewee stated:

If we want to promote the changeability of use in these concepts for senior housing, which is clearly needed, the ventilation should be solved. That is the problem in my opinion. Right now, a hell of renovation is required, even if [an optimal] spatial structure exists.

The interviewee specially emphasized that the transformability of ventilation systems is a key issue for internal transformability in any kind of housing projects, not only those designed for older people.

Compared to building services, structural technology was seen as a barrier to a lesser extent. In Finland, precast concrete wall panels and hollow-core slabs are widely utilized as apartment buildings' load-bearing structure. The technology enables creating fairly long spans and so, provides in principle a relatively good setting for spatial transformability. However, novel structural solutions can introduce new kind of limitations. One interviewee had been involved in designing wooden apartment buildings, which were built out of spatial modules prefabricated from cross-laminated timber (CLT). To maintain economic feasibility, modules' dimensional variation should be restricted within one project. The interviewee explained that it is particularly important to limit variation in the modules' width, as it influences the cost more than that of length. This restricts the design of spaces, as the modules must also be fairly narrow, not more than five meters wide, for transportation. The modularity, narrowness and module repetition with minimal width variation are starting points that limit the variety of possible floor plans. How building services are arranged in these buildings causes an additional restriction. Vertical ducts are often integrated into walls bordering the staircase, so bathrooms must be placed next to them, which delimits the spatial options further.

4.1.4 Other barriers

Some interviewees mentioned inconsistent and occasionally surprisingly strict interpretations of regulations as hindrances for certain transformable dwelling concepts. Since 2007, a small number of neo-loft projects have been built in the Finnish capital region. As these projects are rare, local building inspection authorities have interpreted fire and stair regulations of the national building code differently. The strictest fire regulation interpretation that the authorities first posed would have required to build the intermediate floors inside the lofts out of concrete, which would have seriously hampered the do-it-yourself and transformability idea of the concept. After lengthy negotiations, a less strict interpretation was reached, and the projects were implemented.

Another case in Helsinki (the capital) was less successful. The project's idea was to provide internal transformability by introducing small units which can be joined with adjacent larger apartments. Alternatively, the small units could be used independently as one-room apartments. Consequently, the dwelling distribution and sizes could be altered over time. However, local politicians had earlier established a requirement for apartments' average size in new construction, which had to exceed 75 m^2. In this particular project, the requirement could be met if the small units were joined with the larger ones. Were they kept separate, the average size would remain below 75 m^2. Because the developer marketed the units so that joining them was optional, the requirement might not have been met if all the apartments were sold to separate owners. So, the concept was not approved by the building inspection authority, and it was never implemented. The interviewee described:

[…] the building inspection authority took a really strict stance on this, prohibiting [us] even from making versions where […] there would have been two entrances to the same apartment.

What is more, the national Housing Transactions Act may form an indirect barrier. The Act encompasses paragraphs to protect the consumers. If major faults are found in the dwelling during the first ten years, the developer is obliged fairly strictly to pay compensations for the consumer. To avoid this, developers are often unwilling to consider any spatial or structural solutions that deviate from the standard, which some transformability concepts may require. One interviewee analyzed:

[T]here's an extremely strong Housing Transactions Act which protects the consumer, and very many regulations pertaining to the sound insulation and the like. Therefore, the developers are really cautious, as there will always be the kind of individual buyers and also housing companies[4] *which will then go and search for these mistakes, even with the help of a lawyer.*

Articles of association of housing companies may also act as barriers. The articles are typically quite detailed. As they are confirmed in the general meeting of shareholders, where a statutory majority of two-thirds or, in some cases, a full consensus is required to change them, they are difficult to amend if apartments are transformed. One interviewee postulated:

The possibilities for additional rooms have proved as a little problematic because one always wants, somehow, to fix the number of rooms [in apartments] in the articles of association very unambiguously.

Moreover, to realize the main principle of open building, i.e. to separate the building into durable 'support' and changeable 'infill', design and construction processes, too, should be divided into two phases. This separation does not exist in ordinary housing production, which limits the overall transformability and the choices that become available. The decisions are made in early design phases when most dwellers are unknown. One interviewee pointed out:

A contractor doesn't separate the infill parts and support parts, and the process is such that the infill has to be decided on too early.

Furthermore, restrictive requirements in urban plans were proposed to hinder architects from applying nonstandard building concepts in general, as the plans may include detailed statutes related to e.g. the building's shape, placement, floor height, façade materials, and functions. Lastly, the lack of a consumer-driven demand was mentioned. If a widespread demand would exist, it is believed that the industry would respond with transformable dwelling concepts.

4.2 Barriers in Denmark

Similar to Finland, the main barriers to internal transformability in Denmark include developers' and investors disinterest and cost-optimization. The secondary barriers relate to common construction techniques, regulations, and conventions. Other barriers encompass

[4] Once the shares are sold to the individual buyers and they take on the company management.

public authorities' control over dwelling types; lack of residents' demand, know-how in structural design and circular economy standards; and housing agendas.

4.2.1 Main barrier: developers' and investors' disinterest and cost-optimization

According to the interviewees, the developers of owner-occupied housing and private sector rental housing in Denmark have little interest for the future adaptability of housing. They focus on the current market situation and strive to match the production to the current demand carefully to avoid risks to sales or rentals. One interviewee described:

> *The ones that are building for sale are really market driven. Quite conservative. They're looking at where is the most sale, so they're trying to optimize, or super-optimize, their program to a special demographic in a special area in a special size pattern.*

As developers, pension funds financing private rental housing avoid risks and ideas that deviate from the normal production and look for projects guaranteeing fast and safe returns to their investments. Another interviewee pointed out:

> *Projects are primarily developed by private developers or large pension companies with other focus, and are typically being planned with focus on gaining the shortest possible time between project development and sales – the quickest possible realization of the invested money.*

The interviewees witness that in the large majority of their projects, Danish private sector housing producers strongly emphasize current housing needs and fast delivery, and at the same time avoid risks for sales or rentals. Due to this, there seems to be little space left for considering future developments and changing housing needs, and hence the need for internal transformability. Among the architectural firms of the interviewees, three had experience of a single project commissioned by a private developer with some features of internal transformability. The other three had had no such projects with private developers over the last two decades.

However, not all actors in the Danish housing sector are as disinterested as the pension funds and the developers of owner-occupied housing. Social housing associations have a slightly different perspective. Due to their societal mission, some of them are committed to developing housing through experiments, and internal transformability can be one subject of experimentation. Quite a few social housing developers have had projects containing some features of internal transformability within the last twenty years. The interviewees recognized Lejerbo, KAB, Domea, and 3B as such actors. However, social housing associations have fixed budgets for their projects and need to keep a close eye on the economy, too.

An intensive focus on short-term economics, regardless of the tenure type, creates a barrier to many transformability concepts. It leaves no room for some of the key solutions enabling internal transformability, such as access floor systems, additional floor areas, or second bathrooms in apartments. Internal transformability can usually be included in housing projects on the condition that it creates only minor additional costs, or preferably no extra costs at all. One interviewee pointed out:

> *Most buildings are being built as turnkey projects. And here there is maximum focus on the construction economics, and any solution that deviates from normal construction is, for this reason, deselected if possible.*

4.2.2 Secondary barriers: common construction techniques, regulations, conventions

The emphasis on economy guides developers to utilize the most common load-bearing structural systems for apartment buildings. These systems are not the most favourable structural solutions for producing internal transformability. One interviewee reminded that, with regard to transformability, it is important to consider the geometry and the structural solution of the building together. With this notion, they favoured the principle to avoid internal load-bearing walls and to include additional capacity in the load-bearing structure. However, these principles are often disregarded in housing projects due to economic reasons:

> *We introduce it all the time, but that doesn't mean that the client wants it or the contractor wants it. Most often they don't, because they want to stick exactly to the ordinary practice. […] It's something which is quite technically easy and it shouldn't be that risky, but it's a little more expensive.*

As in Finland, the ordinary Danish practice is to have the walls between apartments as the vertical load-bearing structure. This type of a structural frame is not *per se* a major disadvantage to the adaptability of apartments, as it allows for quite many internal transformability concepts. However, it is a limiting factor to unit size alterations and other adaptations that require crossing the border between apartments, where it hinders the creation of large undivided areas.

The interviewees identified that certain Danish regulations and conventions related to the sizes of apartments and their variation within one building create barriers to internal transformability concepts based on 'switchable' rooms or small apartments that can be joined to adjacent ones (cf. Table 2). In Denmark, small apartments with only one habitable room are rare. They are usually built only to student and youth housing, and ordinary apartment buildings contain them very rarely. In Copenhagen, city requirements establish that in newly-built housing, the minimum floor area of a normal apartment is 50 m^2 in new city development areas and 65 m^2 in existing neighbourhoods (Københavns Kommune, 2020). These numbers represent Danish gross floor areas, which means that the smallest allowed net floor area is approximately 37 m^2. When a one-room unit is required to be as large as this, it becomes problematic to utilize it as a switchable room, i.e. a room that can, when it is not used as a small independent unit, be connected to a family apartment as an additional bedroom. Bedrooms in family apartments are usually not that large, and to connect an overly large unit solely for bedroom use would make the resulting floor plan disproportionate. In student housing, the situation is different as student apartments can be smaller. In Copenhagen, their gross floor area must be 25–50 m^2 (ibid.), so units of an optimal size to act as switchable rooms can be built to student housing. However, student housing regularly contains exclusively small apartments, and combining two or more of them does not usually create a functional larger unit. As student housing and ordinary housing are two different housing categories, and the means to finance them are different, they hardly ever occur together in one building. Consequently, both Danish regulations and common financing structures create unfavourable conditions for transformability concepts based on switchable rooms or small apartments that can be joined with the adjacent ones.

There are also other barriers to them. Joining units this way would create a situation where the merged apartment has two bathrooms. Normally, especially in Danish social housing, even large units have only one bathroom, because having several increases the

construction costs. In the cost-optimized Danish housing market, developers may see the extra bathroom as an unwanted additional cost. However, according to the interviewees, various kinds of switchable rooms, e.g. rooms with a bathroom and their own entrance, and rooms placed between two apartments without a bathroom or entrance, were in fact introduced in some social housing projects before the 2000s, allowing housing associations to gain experience on their market reception. An interviewee pointed out that the associations have had difficulties with the switchable rooms, and are therefore reluctant to include them in current or future projects:

> *The social housing corporations, they don't like this option anymore, because they have experienced that in some places you cannot rent this, or it will be too expensive for people.*

Another kind of barrier to internal transformability is created by ventilation systems. Due to Danish energy efficiency regulations (Bygningsreglementet, 2018), mechanical ventilation with heat recovery is required in housing. In apartment buildings, it is customary to utilize centralized ventilation systems and so, one ventilation duct, either for supply or exhaust air, needs to reach every habitable room. As in Finland, the ducts are usually hidden behind suspended ceilings. Consequently, a considerable amount of spaces within apartments have suspended ceilings and a lower room height. If the room division within an apartment is altered, e.g. a part of living room is converted into an additional bedroom, the existing ventilation ducts with suspended ceilings may hinder the placement of the new partitioning.[5] Additionally, new ducts for supply air must be extended to the newly-created room. So, the way the ventilation systems are currently implemented can make spatial changes within an apartment laborious.

4.2.3 Other barriers

In social housing projects, public authorities' control over dwelling sizes can be regarded as one additional barrier. This touches particularly upon the concepts based on switchable rooms or small units that can be joined with adjacent apartments. In Denmark, municipal authorities are actively involved in the planning of new housing to be built in the municipality, and they often regulate dwelling sizes in social housing projects. One interviewee explained:

> *When you develop social housing, you have negotiations with the municipality what kind of housing do you need, and there you are, in close contacts with the politicians about such things. […] The composition of dwellings in a development is made at political level, and in the dialogue between the housing corporations and the politicians.*

Architects have little say, if any, over the dwelling sizes or types. Consequently, an optimal mix of large and small dwellings, which would be ideal for transformability based on switchable rooms or switchable units, cannot be achieved.

Many Danish developers follow the market demand very carefully, as already discussed. In this situation, it is believed that if a considerable demand for internal transformability

[5] Ideally, the new partitioning would run from floor to load-bearing ceiling; otherwise the ceiling is lower than necessary and the sound insulation between the rooms may be substandard.

would exist, the developers would likely respond. Apparently, such a demand is not currently there. The interviewees reason this with culture-bound housing preferences and economic arguments:

A lot of people don't want to mess with building their own flats. I think that's also a market-driven thing.

The home is often purchased by the family or person for their "maximum investment" opportunity and personal finances. Buyers are usually not willing to pay extra for built-in flexibility.

One interviewee reflected on different building materials and techniques from the viewpoint of their transformability. He believed that wooden structures may be more reversible than e.g. concrete structures due to their jointing techniques and easier reworkability. So, the interviewee considered them as ideal structures to support transformability. However, in Denmark apartment buildings, office buildings, and other types of large buildings are usually built out of concrete. Due to the dominance of concrete, there is a lack of expertise in designing wooden structures. The interviewee considered this as one barrier for the transformability of building structures.

Among the architectural firms represented in the interviews, one office in particular was involved with designing a highly circular apartment building. In the project, transformability and reversibility are considered profoundly, including the dismantlability of the load-bearing structure. At the time of the interview, the project was in the phase where tendering material was being prepared. The interviewee found it problematic that no consensus exists for the definition of a sustainable building or a building drawing from the principles of circular economy, and whether internal transformability is an essential part of it:

Just to be clear on, we don't have a standard what is a circular building. We can't say that we want a circular building.

One interviewee, having discussed the details of various projects and motives for adaptability, wanted to reflect on the general situation of housing design and its current focus areas. They crystallized:

I think also in the debate there's a lot of agendas. It's not only flexibility, it's also co-living, it's community, integrating immigrants…

This is an illustrative remark about the prevailing situation. There are several agendas and societal discourses in the housing sector, and the emphases vary project by project. Adaptability is one of them, and it may or may not be included in a given building project. It is only one aspect among many, and at present not a particularly prominent one.

5 Discussion

We classified the barriers to apartment buildings' internal transformability, arising from the interviews, into three categories according to their relative importance: main, secondary, and other barriers. The main barriers and most of the secondary and other barriers we found resonate with those presented in literature previously (cf. Background). However, some of the secondary and other barriers we uncovered, such as the alleged lack of demand by residents, lack of structural design skills for wooden structures (Denmark), and

experienced difficulties in renting apartments with switchable rooms (Denmark), have not been recognized previously. Even more importantly, our research contributes two novel viewpoints. Firstly, it highlights the context-specificity of some of the barriers. Secondly, it underscores that all barriers are not equal but should be understood hierarchically, i.e. that certain barriers can only be addressed after the more primary ones are solved.

5.1 Shared factors

The interviews show that during the last two decades, Finnish and Danish housing developers have seldom commissioned architects to design internally transformable apartment buildings. Consequently, such buildings are rarely built. This is the general situation in the contemporary housing production, and it is in outline similar in Finland and in Denmark. Both the Finnish and Danish architects considered housing developers' disinterest as the main barrier to implementing adaptability. In both countries, the developers' focus is on economy. Quick and risk-free sales or rentals are the decisive factors for the housing providers. Currently, neither internal transformability, nor other forms of adaptability, are their top priorities in either of the countries. If internal transformability is introduced in a project, it should not induce any extra costs. In fact, the costs and potential benefits of adaptability seem to fall on two different parties: the expenses for the developer and the prospective utility for the residents. Apparently, housing developers are usually not convinced that the extra investment to adaptability could be transferred to the price of housing paid by the end-users, nor that it would bring about a competitive edge in the market.

There are, however, a few exceptions among the developers. In the owner-occupied housing market in Finland, two companies actively advertize housing concepts with some features of internal transformability ('Duo' by Bonava, and 'Neoloft' by EKE). These concepts are occasionally used in the companies' housing projects, although they also supply a lot of 'normal' housing. In Denmark, certain social housing associations, such as Lejerbo, KAB, Domea, and 3B, have introduced ideas that deviate from the ordinary production to develop housing, and among them some concepts with internal transformability have occurred. However, certain bad experiences from renting the apartments out have also discouraged the housing associations from continuing the practice.

A further factor shared by both countries is the construction method. The most common technique to build apartment buildings is based on room-sized concrete panels, transverse concrete walls and pre-stressed hollow-core floor slabs. Even though certain authors (e.g. Živkovic & Jovanovic, 2012) and some of our interviewees consider a structural frame based on columns more ideal, the type of a structure commonly used in Finland and Denmark can provide spans up to 10–15 m. Consequently, fairly large open, undivided space can be achieved inside the building, meaning that the commonly used structural solution does not *per se* prevent from incorporating certain concepts of spatial adaptability into Finnish and Danish housing.

In fact, some of the Finnish interviewees highlighted that the system's capacity for adaptability is often taken advantage of during early design phases. Modifiability of floor plans and apartment sizes within a building during the design phase is a requirement commonly posed to Finnish architects when designing owner-occupied housing. This is because developers want to be able to adjust dwelling sizes to meet the specific demand revealed during the marketing stage of the project, prior to its construction. Occasionally, architects need to prepare themselves for making changes to the apartment allocation even in a late design phase. A common way to meet the expectation is to prepare the design conceptually so that some kind of space zoning, or an imaginary division of the entire floor

into smaller areas that can be combined with one another, exists. However, when the apartment sizes and floor plans eventually become matched with the demand, it is customary that the walls between the apartments are assigned as load-bearing structures. In addition to bearing the loads, thick concrete walls are an easy way to solve fire and sound insulation requirements between apartments. This typically leads to the so-called crosswall frame, where longitudinal walls are non-load-bearing. However, the primary spatial structure within the building becomes cemented. This way, the opportunity for adaptability arising from the structure, capable of covering varying spans and providing a variation of possible floor plans, is capitalized on to meet the demand at the construction stage, but the buildings' future transformability becomes, to some extent, discarded. It is noteworthy that the very same structural system is used for office construction in a slightly different manner, which enables more adaptability. In Finnish office buildings, a common solution is that the longitudinal facades bear the loads, freeing the spaces from dividing structures.

From the interviewees' viewpoint, the restrictions posed by the building services are clearly more decisive than those deriving from the structural frame. Building services' transformability is hardly ever considered in multi-family housing construction in Finland or Denmark. It has been neglected even in projects where spatial transformability has otherwise been taken into account. This is because the developers have oftentimes allowed architects to introduce spatial transformability provided that it does not induce extra costs, which designing and implementing transformable building services would do. Without them, relatively minor modifications to domestic spaces, e.g. splitting up a large room into two small ones, may require fairly laborious construction work related to electrical systems, ventilation ducts, and suspended ceilings. Solutions easing the transformation of building services, such as access floors, are almost non-existent in housing construction in both countries. These facts, in connection with the common decision to make the walls between apartments load-bearing, seriously hamper transformability during use.

5.2 Context-specific factors

In addition to the aforementioned similarities, the interviews also brought out some differences between the two countries, which derive from local market and regulatory conditions. In Finland, some concepts providing internal transformability are currently being supplied in the owner-occupied housing market, whereas in Denmark, it rarely occurs. However, it occasionally appears in Danish social rental housing projects. Transformability concepts based on switchable rooms or apartments that can be joined are particularly interesting, with different experiences in the two countries. In Denmark, such concepts have been experimented within social rental housing, but the landlords have experienced them as hard to rent. In Finland, they have occurred occasionally in owner-occupied housing production in the past, and are even currently supplied to the market by one developer. The concepts seem to be problematic in one market, but viable in the other.

The different experiences on these particular concepts draw attention to the barriers caused by building codes and regulations related to sizing of apartments in the two countries. They seem to hinder transformability based on these concepts, but how specifically, differs between the countries. In Denmark, the minimum dwelling size regulations generally create unfavourable conditions for them, whereas in Finland, a city-specific average dwelling size requirement became an obstacle, at least in the context of one particular project.

5.3 Limitations of the study

As all studies, also this one has limitations built into its design. The qualitative methodology can only produce suggestive information about the barriers' quantitative prevalence. Moreover, even if the interviewees were offered the option to remain anonymous, it is possible that once they decided to disclose their names, they may have regulated how openly they spoke about barriers pertaining to stakeholders important to them. In addition, the number of interviewees was small, which means there may be aspects the specific interviewees have not encountered. However, the pool of potential interviewees was also extremely limited, as so little internally transformable multi-family housing has been implemented in the two countries, and all but two that were identified also agreed to be interviewed. The study may have particularly missed architects who have designed this type of housing which has not reached the implementation phase. Their perspectives on the barriers could be valuable but alas, they are hard to identify and reach.

6 Conclusion

In this paper, we investigated the perceptions of Finnish and Danish architects, who have experience on designing adaptable housing, on the barriers for the more widespread construction of such housing. The architects conceive housing developers' disinterest to include adaptability in their projects as the primary obstacle. The more secondary barriers, identified by the interviewees, result directly from the developers' disinterest. For example, developers do not commission transformable building services, which would support the transformability of the spaces, and usually do not pay architects for designing transformable spaces or for taking up tasks or roles that are necessary for their successful planning, such as the communications towards end-users. All of this would at best induce expenses that the developers consider 'extra'. At worst, the experimental nature of the project might risk its timetable, or the sales, rentals, or consumer satisfaction towards the end product. The same cause-and-effect relationship applies to some of the more occasionally mentioned barriers, such as housing companies' articles of association. There is, in principle, nothing that would prevent from matching them with different kinds of adaptability concepts, but it would require the developer to commission a legal counsel to rethink them. A couple of the interviewees believed the developers' indifferent stance reflects the lack of market demand from the end-users, but the majority of them did not bring up such a belief during the interviews.

Housing is a manifold matter with several, often competing and contradictory interests applying to it. Promoting multigenerational longevity through better adaptability, as it pertains to sustainability, may not be on the top of the agenda for commercial actors in the field. As the public sector's purpose is to advance the common good, governments and cities are often expected to lead the sustainability transition by setting a good example in their own actions and by regulating private actors. Given this, it is noteworthy that some of the interviewees currently experience policy-making and regulation as barriers rather than enablers, and that the publicly-funded social housing sector's commitment to adaptability is incidental at best. If adaptability is indeed accepted as a key factor for sustainable housing, policy-makers should at the very minimum strive for identifying and removing any unintended barriers from the regulation. They should also

consider incentivising or obliging adaptability, as it seems that the market mechanism currently produces it only to a very limited extent. However, the need to inform policy-making better is apparent, since the potential contribution of adaptability to sustainability seems currently to be poorly understood.

Moreover, before policies can be successfully implemented, more understanding is needed on the reasons for the industry's disinterest. In this article, we examined architects' perceptions, but developers, policy-makers, or end-users were not interviewed. A logical continuation of the current study would be to interview them to reach a deeper understanding on their perspective. Presently, the introduction of adaptability takes place almost solely in the context of architectural competitions, or relies on the personal interest of individual architects, who do it out of professional ambition or as a contribution for the common good. This, surely, is not a sustainable situation in the long-term.

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