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Housing proposal designed by Krook & Tjäder (architectural office) and Erik Larsson bygg (developer) in a design developer competition 2020 organized by Mark municipality in Sweden.

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AVOIDING MACRO MISTAKES: ANALYSIS OF MICRO-HOMES IN FINLAND TODAY

SOFIE PELSMAKERS, SINI SAARIMAA AND MARI VAATTOVAARA

Abstract

In many European cities, there is an increased construction of "micro-homes", and in Finland, they now make up a large proportion of newly built dwellings. This article analyses micro-homes, using generally accepted housing design quality indicators, to evaluate the claimed potential of micro-homes as a solution for sustainable urban housing. A sample of 60 recent residential buildings in Finland was analysed, representing 4007 urban apartments, of which 40% were micro-homes. The analysis highlights that the majority of Finnish micro-homes do not meet generally accepted housing design quality indicators and they fail to provide sustainable living over time. The great majority (79%) of the studied apartments were small, "tunnel-like" micro-homes, significantly compromising good housing design quality principles such as natural light provision and spacious and flexible living. Our findings challenge the justification of the prevalence of the construction of these units – even more so given that the Finnish Land Use and Building Act has required sustainable housing solutions since 2000. Findings also highlight the significant shortcomings of micro-homes, and the article addresses the urgent need for different design approaches to enhance housing design quality to support more sustainable housing development.

Keywords:
micro-homes, sustainable housing, housing design quality, studios, adaptability, sustainability

Introduction

Apartment buildings are central to urban housing. They provide practical solutions for the high price and limited availability of land in cities and to house the urbanising population. Globally, the majority of people already live in urban areas, and this proportion is expected to increase even further (UN, 2018). In Finland most new homes are urban apartments, and this is similar to elsewhere in the Nordic region (e.g., Vainio, 2016).

Small-sized apartments of less than 37 m² are also referred to as studios, in this article 'micro-homes', and typically have no separate bedroom (Boeckermann Kaczynski & King, 2018; Shearer & Burton 2018). In Finland, there are 100,000 units below 30m² and a total of 15% (447,000) studio apartments without separate bedrooms[1] with an average size of 34 m² (Official Statistics of Finland, 2018). Thirty percent of the Finnish housing stock are one-bedroom apartments (902,000) with an average size of 54 m² (Official Statistics of Finland, 2018). Due to the highly profitable model for developers to allocate as many small units as possible in urban developments, there has been an increased proliferation of micro-homes since 2010 (Karikallio et al., 2019, fig. 2). For example, in 2018, 40% to 45% of new dwellings were studio apartments in Turku and Tampere respectively, with over 35% in Finland's other main urban areas, with the exception of Helsinki (23%) – see Figure 1 (Heinämäki, 2019). These statistics highlight the prevalence of micro-homes; there is thus a need to investigate them more closely as a sustainable solution for housing.

1 In Finland, apartment types are based on the number of habitable rooms, excluding kitchen, bathroom, entrance hall and walk-in closets for example.

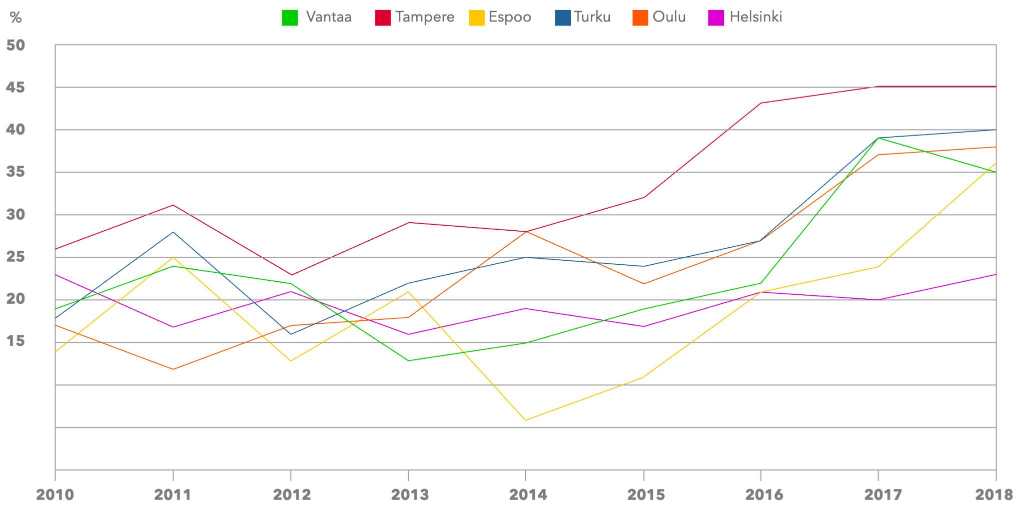

Figure 1
Urban housing supply in Finland's cities since 2010 and the proliferation of small units.
SOURCE: ADAPTED FROM HEINÄMÄKI (2019).

This article investigates housing design quality in new Finnish housing production, and it focuses on micro-homes as it is one of the most prevalent apartment types being built in Finland's largest cities at present (Heinämäki, 2019). Housing design quality refers to the quality of the design characteristics of the internal environment of housing (e.g., size, floor plan, services), but also the external environment (e.g., accessibility) and sustainability (e.g., energy efficiency), to create desirable, sustainable and healthy homes "to meet identified needs in places where people want to live" (Housing Corporation England, 2007, p. 4).

The overall aim is to study the housing design quality of micro-homes and their prevalence in the current Finnish apartment production. The research questions in this study are: *What kind of micro-homes are currently being built in Finland, and what is the housing design quality of these micro-homes?* Firstly, existing research about micro-homes and housing design quality indicators are presented, followed by research methods, including sample and case study selection. In the findings and analysis section, a sample of 60 housing blocks is described, and a smaller representative sample of two case studies is analysed in more detail, highlighting specific characteristics and problems of the studied micro-homes. In the subsequent discussion, new knowledge about micro-homes is explored and summarised in the conclusion.

Background

The construction of micro-homes has often been justified by the large and growing number of people living alone (Official Statistics of Finland, 2019) and by the perceived ecological benefits of lower energy use and limited consumption possibilities when living in small spaces (Saxton, 2019; Häkkinen & Kangas, 2012, p. 3). Smaller units are often suggested to support densification of city-centres when nearby urban services support compact living. Micro-apartments might provide residents with more affordable housing, especially in urban growth centres (e.g., Bäckgren, 2018; Greenspan, 2016; Geffner, 2018); for example, studio-living reduces both monthly rental costs (or capital costs if purchased) and monthly operational costs. While the total number of housing units has increased rapidly in the past 25 years, this has been achieved through reduction in floorspace (i.e., through the provision of smaller units) – see Figure 2. (Rakennustehollisuus, 2020).

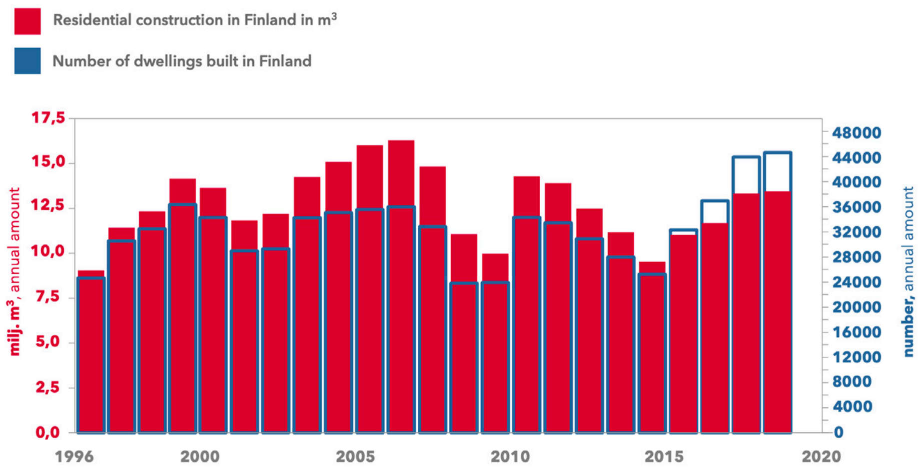

Figure 2
Construction of Housing in Finland since 1996 by volume (m³, red) and by the number of units (blue line). The 2018–19 overall volume (m³, red) seems large compared to 2012–2017 but significantly lower when compared to 2004–2008. In 2004–2008, the number of units (blue line), was significantly lower than in 2018–2019, when number of units hit a peak. The combination of an increase in number of units constructed, but not in overall m³, indicates a reduction in floorspace of units in the last few years (adapted from Rakennustehollisuus, 2020).

Compact living can, on the other hand, lead to overcrowding; high-rise buildings are especially found to be less satisfactory overall (e.g., isolation and potential unsuitability for small children), depending on a dweller's life stage, socio-economic status and their available housing choice (Larcombe et al., 2019; Gifford, 2007; Burridge & Ormandy, 2005; Kortteinen, Tuominen & Vaattovaara, 2005). Moreover, solo dwellers often do not wish to live in studio-sized apartments (Backman, 2016, p. 59), suggesting that the supply of micro-homes does not match the dweller's actual needs or desires (Tervo & Hirvonen, 2019). Their design is typically based on compromised space standards, on the assumption that dwellers neither spend any substantial time at home, nor raise a family, nor entertain at home. Furthermore, a 2020 survey highlighted that 86% of 20–29 m^2 apartments in Finland are not owner-occupied, indicating that they are not perceived as permanent housing solutions (Official Statistics Finland 2017b).

The increasing concerns about the reduction in housing design quality in urban areas (see e.g., Finlay et al., 2012; Punter, 2010) are revealed in Finland by an increasing number of small studio units (Karikallio et al., 2019), deeper building plans and poor daylighting (SAFA, 2020; Saarimaa & Pelsmakers, 2020). Smaller units are also found to be more prone to summertime overheating in Finland (Sukanen, 2020), as also reported elsewhere (e.g., Taylor, 2014). These tight space provisions and housing design quality issues were underlined by the coronavirus pandemic, when dwellers were mostly confined to these difficult living environments (e.g., NHF, 2020; Hätälä, 2020). In the case of micro-homes, dwellers not only lived in, but also worked or studied from their single roomed micro-home, possibly shared with another person. When shared with a child, the micro-home was also a playground and home school. In addition to the pandemic, a changing demographic with different user needs highlights the necessity for a variety of adaptable spaces. For example, a survey of 1000 Finnish respondents showed that 91% of those living in apartments would like to make changes in their home (Kempas, 2020). Over 30% of respondents desired more space in their apartments and 17% a large enough garden (Kempas, 2020).

The rise of solo dwellers and shrinking apartment sizes

Three major changes influence housing design: shrinking household size, population ageing and increasing immigration and multiculturalism. For a long time, the nuclear family constellation has been at the heart of housing design influences (Saarikangas, 2002; Pirinen, 2014), with small units being a steppingstone towards later family life. However, the nuclear family is no longer appropriate as the main design influence, given the increase of small and one-person households. For example, in Finland there has been a steady decline in average household size from 3.34 in 1960 to the current 1.97 persons per household (Official Statistics of Finland, 2019; Eurostat 2020a), reflected in a low birth rate of just 1.49 (Official Statistics of Finland 2019).

In Finland, more than 1.2 million people make up one-person households, termed "solo dwellers" (Tervo & Hirvonen, 2019), overall making up about 45% of all Finnish households (Official Statistics Finland, 2019). Ageing of the population is one of the main drivers of the predicted rise of solo dwellers. Already now, Finland has one of the highest proportions of citizens over 65 years old in the EU (21.8% of its population compared to the EU average of 20.3% (Eurostat, 2020b)). As Finland's ageing population is increasing, the number of older people living alone is also expected to increase. Concerning solo-dwellers specifically, men under 30 and women over 65 years-old are heavily represented (Official Statistics of Finland, 2019), and people aged over 75 are the largest proportion of solo dwellers overall – with every second person living alone (Official Statistics of Finland, 2019).

However, a direct link cannot be drawn between the growing number of single people and the need for micro-homes (Tervo, 2021). This is because solo dwellers have diverse life situations and spatial needs that small micro-homes do not necessarily meet (see for example Tervo & Lilius 2017; Tervo & Hirvonen 2019; Tervo, 2021). For example, less than ten percent of solo dwellers considered homes smaller than 40 m^2 suitable, while the majority expressed preference of homes between 40–59 m^2 or larger (Backman, 2016). Additionally, access to a larger number of rooms seems to be linked to the quality of social life for some of the solo dwellers (Tervo & Lilius 2017).

Finally, Finnish families are now more diverse, pluralistic and multicultural than ever before (Andersson et al., 2010; Vaattovaara et al., 2010; Keurulainen, 2014). Hence, housing options should reflect the diverse needs of diverse families, including tele-working situations, multi-generational and extended families (Kukko, 2006), in addition to families with a fluctuating number of members (e.g., children moving weekly between different places) (see for example van Kempen & Özüekren, 1998). Increasing the quality, size and diversity of housing options is even more important in a more multicultural, diverse and tele-commuting society.

Demographic change: Implications for housing design

An accessible and versatile housing stock that offers various living alternatives to serve a diversity of people (including older people) is needed to support high living quality for people with different life situations (see e.g., Tummers, 2015). Moreover, when an older person is housebound due to health issues, the home environment and living concepts that enable a social life and contact at home become even more important for mental wellbeing (Iwarsson et al., 2007). For example, to counter high levels of loneliness in the older population, important social activities include entertaining and receiving visitors at home, or to look after grandchildren from one's home (Tsai, Motamed & Rougemont, 2013; Kemperman et al., 2019; Quirke, König & Hajek, 2019). Yet this is difficult to offer in the spatial constraints of a micro-home.

Notwithstanding the needs of current and future residents, spatial needs and priorities change over time, driven not only by individual but also by societal changes. For example, further digitisation could lead to increased flexible tele-working from home, requiring a separate working space. Hence, the adaptability of the urban housing stock to change over time is not only necessary for individual residents (whether they are young or older solo dwellers), but also a crucial consideration for estate owners if assets are to retain their value over time. As such, not only the proportion of micro-homes in new developments is highly relevant, but also how micro-homes have been designed, where they are located and how they may adapt to different users' needs to allow future changes. The following section further explores the importance of good housing design quality.

Principles of good housing design quality

Housing design quality relates to aspects from neighbourhood settings and external contexts to interior dwelling characteristics and sustainability aspects, such as acoustics, good indoor air quality and energy efficiency (see e.g., Bonaiuto et al., 1999; Nylander, 2002; Drexler & El Khouli, 2012; Burridge & Ormandy, 2005). However, this article focuses mainly on the floorplans of dwellings, specifically on good housing design quality principles and the interconnections with sustainability aspects in support of residents' health and well-being. Good housing design quality has been studied from many perspectives (see for example Nylander, 2002), including adequate space provision (e.g., Foye, 2017) and perceived density (Fisher-Gewirtzman, 2017; Solari & Mare, 2012; Evans, Leopore & Schroeder, 1996), or spaciousness (Coffin & Young, 2017). Other aspects studied are related to activities, use and functionality (Djukardi & Srinaga, 2019; West & Emitt, 2004; Ozaki, 2005), spatial organisation and efficiency (Kutá & Česelský, 2015; Raviz et al., 2015), privacy (Tomah, Ismail & Abed, 2016; Kennedy, Buys & Miller, 2015), visual comfort and daylighting (Dogan & Park, 2020; Shafavi et al., 2020). There is also a significant body of work related to accessibility (Bordas Eddy, 2017) and the ability to adapt in various ways (e.g., Habraken, 1972; 1998; Hertzberger, 1991; Brand, 1994; Schneider & Till, 2007; Leupen, 2006; Schmidt & Austin, 2016; Krokfors, 2017; Pinder et al., 2017; Braide, 2019). All of these aspects also relate to research about residents' values in relation to residential space (Finlay et al., 2012; Kuoppa et al., 2019; Tervo, 2021), housing satisfaction (Eklund et al., 2017) and spatial solutions that affect residents' well-being (Baker & Steemers, 2019).

Moreover, in the field of architecture there is a long trajectory of research into the design of housing and floorplans of dwellings, including the analysis of different dwelling characteristics in relation to dwelling types and typologies (e.g., Kaasalainen & Huuhka, 2016), including changes in time (Hanson, 1999; Kärrholm & Kopljar, 2020). The review of floor plans has been a key analysis method for understanding good housing design quality principles, such as adaptability and flexibility (e.g., Rabeneck et al, 1973, 1974; Schneider & Till, 2007). As long ago as the early 1900s, modernist housing design was concerned about the efficient use of "minimum dwelling" space, and, as such, the adaptable capacities of the floor plans have been studied for a long time (e.g. Rabeneck, Sheppard & Town, 1973; 1974; Schneider & Till, 2007, p. 13-32; Leupen, 2006, p. 9). The connections between floor plans and housing design quality principles are also presented in design guidelines and evaluation methods (see e.g., Drexler & El Khouli, 2012), as well as Finnish national housing design regulations and guidelines (e.g., RT 103260, 2020; ARA, 2019).

While there are many housing design quality principles, nine generally accepted key indicators are crucial for achieving good micro-home design quality – see Table 1. These principles are linked to sustainability principles and also resident's health and well-being. A commonly understood indicator of good design is good access to daylighting, sunlight, views of the sky and connection to outdoors – see Table 1 [1, 2] (e.g., Kuoppa et al., 2019; Drexler & El Khouli, 2012; Finlay et al., 2012; Burridge & Ormandy, 2005; Nylander, 2002). For example, minimum daylight factors[2] of 2% in living spaces are required to avoid reliance on artificial lighting, although 5% is recommended, which also provides more pleasant and bright spaces and positively affects residents' well-being (Lelyveld & Livingstone, 2018; Baker & Steemers, 2019). In addition to adequate daylight, sufficient space has been seen as an important design quality (Table 1 [5]), in addition to a sufficient and useful apartment entrance (Table 1 [3]), other "secondary spaces" and access to external outdoor private and communal spaces (e.g., Finlay et al., 2012; Kuoppa et al., 2019; Drexler & El Khouli, 2012; Burridge & Ormandy, 2005) – see Table 1 [6]. Unsurprisingly, the presence of spacious main living spaces (i.e., shared spaces such as living, kitchen and dining areas) to enable socialising are considered important, as is private space away from other household members (Table 1 [5]) (Finlay et al., 2012; Drexler & El Khouli, 2012). A lack of access to adequate space, good daylight and sunlight in the home is considered a health and sustainability hazard, potentially leading to reduced sleep, compromised wellbeing and increased energy use (Keall et al., 2010).

Furthermore, choice of apartment type is seen as an important housing design quality indicator (Table 1 [4]) (Drexler & El Khouli, 2012). The ability of a space to change over time and the potential to use spaces in multiple ways are also considered important aspects of providing good housing design quality (see Table 1 [7, 8]) (Habraken, 1972; 1998; Hertzberger, 1991; Brand, 1994; Schneider & Till, 2007; Krokfors, 2017; Kuoppa et al., 2019, p. 16; Burridge & Ormandy, 2005; Finlay et al., 2012; Drexler & El Khouli, 2012). The latter includes the possibility of a space to suit "multiple functions and furnishings along changing life situations" (Kuoppa et al., 2019, p. 16), i.e., the capacity of a space to be furnished in a variety of arrangements (Table 1 [7]). Benefits of adaptable dwellings for residents include

2 The daylight factor (DF) determines the availability of daylight in a space, based on the proportion of light available from outside, assuming a uniform or overcast sky regardless of weather conditions and without taking into account the orientation, or movement of the sun. Typically, a DF of 2% is considered minimum for acceptable daylighting in habitable rooms, though 5% is recommended (Lelyveld & Livingstone, 2018). A 5% daylight factor means that 5% of the daylight outside is measured internally.

long-term social sustainability by providing stability and agency, when dwellers can stay in the same community for longer if their spatial needs can be accommodated through adaptability, rather than moving home (Femenias & Geromel, 2019). Well-being is supported by different levels of dwelling choice and adaptability (Table 1 [4, 7-9]), fostering inclusion of a diversity of residents and a more permanent community, which in turn supports social bonding and life satisfaction (Lee & Park, 2010). All of these aspects contribute to housing satisfaction, which increase overall quality of life (Lee & Park, 2010). Finally, long-term adaptability also ensures a building's longevity and avoids a building's premature obsolescence and hence supports circular economy principles (Pelsmakers, Poutanen & Saarimaa, 2020).

Applicable adaptability principles to micro-homes are apartment adjustability and apartment divisibility (or connectivity) – see Table 1 [8, 9]. Adjustability refers to configurational adjustability that the dwellers themselves can create in the space (using different means) without the need to change load bearing elements or shared building services. It "involves ensuring that the 'stuff' inside the building, such as (…) fixtures (…), can be reconfigured" to meet changing needs (Schmidt & Austin 2016, p. 70). Apartment divisibility (or connectivity), also referred to as elasticity (Braide, 2019), relates to changes that lead to a change in the size of the dwellings. This can entail, for example, changing the size of apartments in relation to each other by dividing or connecting. Because the space in micro-homes is so small, other forms of adaptability are not applicable to micro-homes. For instance, the flexible location of services in false floors or ceilings to allow wet rooms to be freely re-located has little relevance if there simply is no space to relocate the wet room.

Clearly, several housing design quality indicators are also interrelated; for example, the spatial adjustability potential of apartments is enabled by the presence of good daylighting (or hindered by its absence) (see Saarimaa & Pelsmakers, 2020). Table 1 summarises the above-mentioned housing design quality principles.

Table 1
Summary of housing design quality indicators at the apartment level as presented in literature. Indicators were selected from Drexler & El Khouli's (2012) "Housing Quality Barometer", unless stated otherwise.

Housing Quality Indicators (apartment scale)			
Design Quality	**Summary**	**Best practice recommendation**	**Below average practice**
[1] Natural lighting	Presence of daylight and sunlight at different times of the day and seasons, especially in the living room. Reduced energy use and increased well-being.	Main living spaces should have natural light in at least two directions. Where single aspect, the plan must be shallow, i.e. usually less than twice the floor to ceiling height of the glazed façade (Brophy & Lewis, 2011). Daylight factor of 5% in living spaces (Lelyveld & Livingstone, 2018).	Where no direct sunlight in winter, 5 to 6m is typically the maximum depth of plan to be potentially daylit from one direction only (based on 2x the space height, Brophy & Lewis, 2011). Daylight factor of less than 2% in living spaces (Lelyveld & Livingstone, 2018).
[2] Connection to outdoors	Number and quality of views. Proximity of kitchen area with outdoor area, window in the kitchen area.	Windows in as many directions as possible, attractive views; views of the sky (Burridge 1993). Kitchen should be located on an external wall and have at least one openable window to ensure good ventilation and lighting, also giving views of a private external space.	Windows in one direction only if the plan is deep; kitchen is not located on an external wall and has no windows.
[3] Apartment entrance	Usability of the hallway area (spacious enough to receive guests, well-lit entry hall).	Niches that can be used as work, play or storage areas; width of at least 1.6 to 1.8m wide, naturally lit and 2.4m deep.	No usable space.
[4] Choice of apartment	A diversity of apartment choice should be available in every development, to provide for a diversity of user needs and community; enabling dwellers to potentially find a home without having to leave their familiar environment.	No type of apartment should be represented by more than 30%; small apartments with 2 rooms or less are grouped as 'one type'.	Where one type of apartment is present by more than 70%.
[5] Spacious living	Spacious main living spaces (i.e. shared spaces such as living, kitchen and dining areas) to enable socialising. Private space away from other household members (Finlay et al. 2012).	Separate areas for socialising away from private rooms.	No separation of communal and private spaces possible.
[6] Private open outdoor space	Each unit to be provided with an external private area allowing different activities, directly accessible from the home.	$4m^2$ in size/room and facing towards the sun.	If 1 m^2/room or less in size.
[7] Furnishability	Choice to where dining table and beds are positioned in a room, i.e. more than one position is possible.	More than one position possible.	Only one position is possible.
[8] Adjustability (Adaptable dwelling)	The dwellers themselves can reconfigure the space without the need to change the long-lasting parts of buildings, such as load bearing elements or shared building services (Schmidt & Austin 2016).	Various options for interior configurations.	No options for interior configurations.
9] Divisibility (or Connectivity)	Apartments that can be modified in size, i.e. joining or division of apartments without the need for major modifications.	Where more than two thirds of all apartments in a development can easily change in size.	No apartments can be modified in size.

Research methods

Sample selection

The main material of the article consists of 60 selected apartment buildings built in 2019–2020 in Finland, or to be built between 2021–2022 in Finland's largest cities. The 60-building sample was obtained by searching for new "for sale" apartments in Finland's largest urban areas (i.e., Helsinki, Espoo, Tampere, Vantaa, Oulu and Turku) at the Finnish housing sale website Etuovi at the turn of 2019–2020. Identification of a sample of the current housing stock was undertaken by selecting buildings that first appeared in the search that were not identical, until data saturation was achieved (i.e., when the characteristics of new buildings were similar to those already selected, as also described in Saarimaa & Pelsmakers, 2020). This sampling strategy was intended to capture a cross-section of the current housing production in Finland, representing 4007 apartments. From the larger sample, a representative selection of two case study buildings and four micro-homes was selected to study in more detail. These were selected based on the larger sample's characteristics, such as being representative of the sample's most common staircase locations and similar micro-home characteristics found in the larger sample and as further described in the analysis and findings section. The same two case studies were also subjected to a study by Saarimaa & Pelsmakers (2020), which analysed adaptability of multi-room apartments, but specifically excluded micro-homes.

Mixed methods

A mixed method was used in the analysis. First, the selected 60-building sample was studied, and the micro-homes located in them were described statistically and typologically. Second, the entire micro-home sample of 4007 units was analysed concerning the indicators of floor area, window openings, divisibility or connectivity and connection to outdoors (i.e., the number of windows and whether the micro-home was single or dual aspect; easy combinability with other units in theory, or if they had been purposely designed for this, the types of balconies). Thirdly, the four selected representative micro-homes were investigated in relation to the nine housing design quality indicators as synthesised in Table 1 and presented in Table 2. These indicators, based on existing research and as previously described in this paper, are used as a "traffic light" checklist system (see Table 2) when examining the design and concerns of the micro-homes sample and the two case studies in this article. The use of these generally accepted indicators helped to investigate (and compare) different housing design quality principles of micro-homes in more detail.

Moreover, housing design quality was investigated in more depth through the study of architectural floor plans and interior spatial images, taken from marketing material showing furniture layouts, window locations etc. Additionally, daylight conditions were studied in more depth, using Velux Daylight Visualizer 2[3]. The sizes of the windows and locations of the overhanging balconies were deduced from the available marketing material, but no other external obstructions (such as adjacent neighbouring buildings) were modelled, thereby optimising the available daylight, and representing a best-case scenario evaluation of daylight conditions. Finally, design as a research tool helped to understand and visualise issues in the current housing production as well as to propose alternative scenarios in some instances (see e.g., Vervoort & Pisman, 2015).

Analysis and findings

Sample characteristics

As previously reported, between 23% to 45% of the Finnish housing production in 2018 were micro-homes, depending on which city location (Heinämäki, 2019). Similar findings were made based on the sample of 60 buildings in this paper, overall capturing 4007 dwellings in 6 of Finland's largest cities. In this sample, there was a 40% prevalence of micro-homes, i.e., 1610 units below 37 m^2. Additionally, there were 31% one or two room units over 37 m^2 (1253 units)[4]; 21% three room units; nearly 7% four room units; and only 0.5% above four room apartments. The sampled buildings in Turku had the highest proportion of micro-homes (50%), followed by Oulu and Vantaa (44%), 42% in Tampere, 35% in Espoo and 29% in Helsinki.

These statistics highlight the prevalence of small units (i.e., zero to one bedroom), accounting for a total of 71% (or over 2850 units) in the sample. According to the housing design quality indicators, this is below average practice; best practice recommends a maximum 30% of one apartment type (see Table 1 and 2 [4]). This suggests little diversity in housing provision in this sample and raises questions about the wider Finnish housing production. Moreover, the average size of micro-homes in this sample was 29.4 m^2, 15% below the current Finnish country-wide statistical average of 34 m^2 (Official Statistics of Finland, 2019).[5] Especially their small size raises questions about their quality and their ability to meet or adapt to different user needs today or in the future – this is investigated in the next sections.

In the diverse sample of 60 buildings, housing blocks with central stair cores and middle-corridor circulation were the most common building types, leading to a large number of single-aspect units (see also Saarimaa & Pelsmakers, 2020). Note that most of the central stair core buildings also included some kind of middle-corridors, "gradually changing to elongated mid-corridor buildings" (Saarimaa & Pelsmakers, 2020). Two representative buildings with these circulation characteristics were studied in more detail (see Figure 3). These two selected case studies

3 Default values for wall finishes were assumed and in windows, glass 78% transmittance was used.

4 In Finland, a two-room apartment typically is a one-bedroom dwelling with a separate bedroom, and a combined kitchen/living room. However, the sample here includes one roomed apartments over 37 m2 in the "1 bedroom sample" as they did not fit the micro-home criteria

5 Note that in our sample, all apartments under 37 m2 were classified as micro-homes and some of them were small one-bedroom apartments; if the delimitation had been set for only one-room studios, the average floor area would most likely be even lower for the one-room micro-homes only.

were located in Oulu (central stair core building 1) and in Espoo (middle-corridor building 2).

Figure 3
Building block plans of the two representative case studies: central stair core building 1, located in Oulu on the left and the middle-corridor building 2 located in Espoo, on the right. The grey colour highlights the focus apartments in this study.

Sample characteristics and housing design quality evaluation of micro-homes

Based on the 60-building sample it became apparent that the micro-homes share many similar characteristics. Of the 4007 apartments, 40% or 1610 were micro-homes and they can be categorised into two main types:

- **Type A** micro-homes were tunnel-like small rooms that had an elongated rectangular plan and were on average 28.8 m² in size, though some were as small as 20 m². They represent 79% of the sampled micro-homes, or 1277 units, in the 60 buildings. Type A apartments ranged generally from 6 to 8 m in internal room depth, though up to 9 m internal room depths were also found. The most prevalent units were 31 m² and 28 m² in size, with 15% prevalence of each. In many instances, these elongated rectangular micro-homes were placed side by side in repeated rows in the building. The two case studies selected for more detailed investigation illustrate these different characteristics, which also affects their quality – see micro-homes Type 1-A and 2-A in Figure 4.
- **Type B** micro-homes were typically units with an average size of 35.3 m² (and none below 29 m²); they had a squarer shape than Type A and represented just 12% of the sampled micro-homes, or 193 units – see Figure 5. In Type B units, the unifying factor is the presence of a small, separated room or an alcove. In B-types, the configuration

varied more widely; for example, the relationships between different dwelling activities (entrance, cooking) and apartment forms were more diverse than in A-types.

Another 9% (or 140) micro-homes with an average size of 29.1 m² did not strictly fit the above two categories as a result of non-regular building forms due to the city plan (i.e., a non-perpendicular shape). The article therefore focuses on Type A and B micro-homes, which represented a total of 91%, or 1470 micro-homes, in this sample. The two selected case studies and the four micro-homes as represented in Figures 4 and 5 characterise recurring micro-home designs and characteristics of the larger sample.

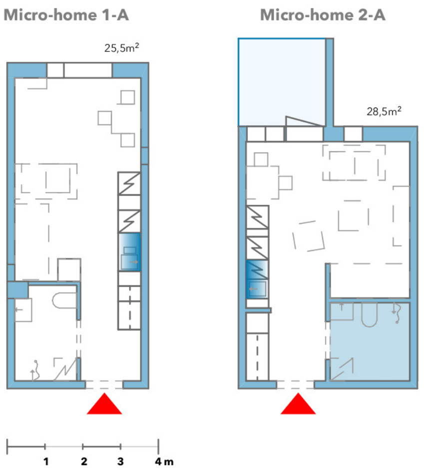

Figure 4
Examples of A-type micro-homes representing 79 % of the micro-homes in the 60-building sample: case study 1-A (left) and 2-A (right).

Figure 5
Examples of B-type micro-homes; case study 1-B (left) and 2-B (right), representing 12 % of the micro-homes in the 60-building sample. There were two versions of type 1-B in the case study building with the same size, internal configuration and balcony location and size, but with a small difference in the windows and balcony walls.

Type A apartments – general evaluation

With a 79% occurrence, the smaller micro-homes of the two case studies represented the first and most common A-type well (see Figure 4). This recurrent tunnel-like micro-home type had both more narrow and longer models (such as the micro-home example 1-A) and slightly wider and shorter models (such as the micro-home example 2-A, Figure 4). The apartment entrance was usually at the short end of the elongated rectangle opposite to the main apartment's window. This almost invariably makes the entrance a space without natural light, the provision of which was highlighted as best practice (see Table 2 [3]). Typically, these micro-homes only had a window in one direction (only 10% had windows in more than one direction) and the plan was deep (typically six to eight meters) – this provision is considered below average practice (Table 2, [1, 2]).

Due to accessibility regulations, the sizes of bathrooms ranged from around 4 to 6 m^2, leaving less than 25 m^2 space for all residential activities excluding bathing, in the case of an average sized micro-home in this sample. The bathroom was usually situated adjacent to the entrance with storage space placed opposite to the bathroom door. A small row of kitchen cabinets was typically located either at the end of the hallway furniture, on the long side of the elongated rectangle (see example 1-A and 2-A) or on an internal bathroom wall, missing out on the best practice opportunity for direct access to a window (see Table 2 [1, 2]). This has implications for residents' health and well-being and increased energy use, due to increased reliance on artificial lighting (Keall et al., 2010). While Finnish accessibility regulations ensure that there is space of a 1.3 m diameter at the entrance, leading to the overall width of the entrance typically meeting the best practice recommendation, there were only few storage space options in the apartments, and in many instances the hallway usability was hindered by cabinets directly in front of the entrance, or poorly placed door swings into the entrance space. (Table 2, [3, 5]).

Generally, the furnishing of these A-typed micro-homes was difficult. The limited space, combined with a narrow and long spatial form, limited different furnishing options, and inevitably led to a situation where the bed is close to the kitchen and its appliances, such as the oven or fridge (see Figure 6 and Table 2, [5, 7]). In the instances where the kitchen furniture was on the long side of the apartment, the bed was typically situated next to the bathroom wall (see example 2-A). It was difficult to change the furniture organisation, because then the bed was located in the middle of the apartment or in front of the window, which were unrealistic and unusable options. Hence, these types of micro-homes were not furnishable in a diversity of ways, as recommended as best practice (Table 2 [7]). Furthermore, this dwelling type did not have a separate, more private space; instead, relaxing and sleeping take place in the same open kitchen-living room area, highlighted as below average practice (Table 2 [5]).

Figure 6
A real interior of an A-type micro-home. The picture illustrates difficulties of furnishing A-type micro-homes with normal-sized furniture. The table is clearly undersized, and the sofa has been placed into a poorly usable corner. The close connection between the kitchen and the bed does not guarantee a peaceful resting place. The original image was anonymised by converting the rendered drawing into a line drawing in Photoshop; no proportions or qualities were changed in this process.

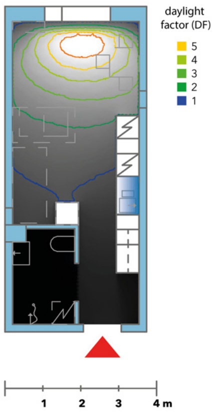

Figure 7
The daylight factor (DF) modelling of the micro-home example 1-A: despite its small size, analysis revealed the dark entrance and the limited spread of natural light in a deep plan unit.

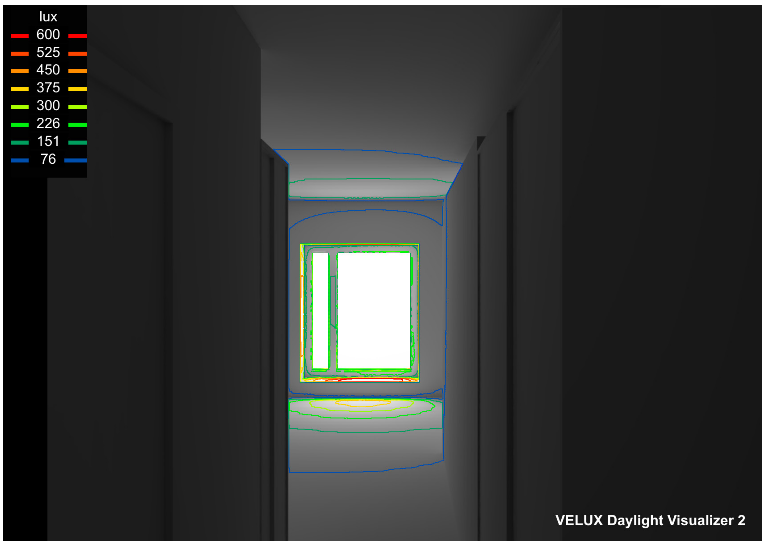

Figure 8
Illustration of illuminance of apartment 1-A during March at 12:00, with overcast sky.

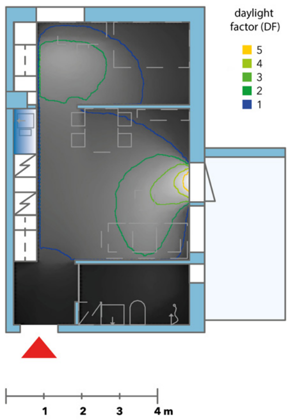

Figure 9
The daylight factor modelling of the micro-home example 1-B. Daylight from two directions made the lighting more even, but its small window sizes meant that daylight provision was still below minimum recommendations.

Type B apartments – general evaluation

Representing just 12% of the sample of micro-homes, the type B micro-homes were less prevalent with an average floor area of around 35 m², slightly above the current average Finnish micro-home of 34 m². These micro-homes were squarer in shape and included a possibility for a separated space, in addition to an open kitchen-living space. The larger micro-homes of the two case studies represented these B-types well, see Figure 5. There was more form-related dispersion in these B-types than in the first A-type: for example, window openings might only be on one side (78% of the sample, see Type 2-B) or on two sides of the apartment (22% of the sample, see Type 2-A) – the latter is considered best practice (see Table 1 & 2 [1, 2]; see also Figure 9).

In these B-type units, the bathroom was also located on the entry side of the apartment. The kitchen could be a continuum of the hallway storage furniture (as in the A-type described above, see example 2-A and 1-B), or it could be a corner kitchen next to the entrance (see 2-B). In many situations, the kitchen was located close to the entrance and the bathroom door, with no connection to a window, or to outdoors, and it had no proper daylight (Table 2, [1, 2]). Sometimes the kitchen was located on an external wall, creating opportunity for a window and good daylighting in the kitchen area. This B-type also often led to challenging furnishing, because the actual furnishable open kitchen and living space often remained only around 13 m² in size[6]– see Figure 10, compromising the furnishing of dining and living space, which was highlighted as an important housing design quality indicator – see Table 2, [7].

6 This is the area when not taking into account the separated alcove or a bedroom nor entrance or kitchen cabinets and mandatory passages in front of them, see Figure 10.

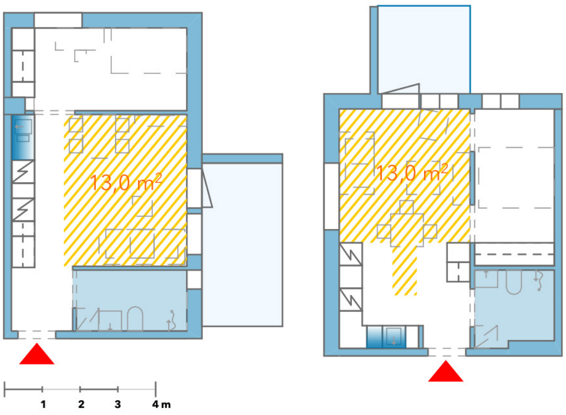

Figure 10
Type 1-B (on left) and 2-B (on right); the actual furnishable open kitchen and living space was typically small, here about 13 m² in size. In reality, furnishable open kitchen and living spaces would be even smaller when passages to the bedrooms and balconies are considered.

Type A and B apartments: Access to an adequate private outdoor space

Excluding the presence of French balconies, 69 % of the Finnish micro-homes sample had an outdoor space, which was more common in type B micro-homes (98%) than in type A micro-homes (61%) (see Table 2, [6]). However, the characteristics of outdoor spaces were very similar in both types: in principle, the outdoor space was located in front of the main window of the apartment (and thus often reduced the only daylight source in single aspect units). A-type micro-homes were usually single aspect, sometimes with a French balcony door (37%) (see example 1-A). Only 2% had no balcony, but 61% of these A-Type micro-homes had a full balcony (see 2-A). Although the existence of the outdoor space is seen as part of good housing design quality, the location of the outdoor space in front of the only window made the deep end of the long A-Type apartments even darker. B-type micro-homes were always equipped with a balcony; including 8% with a sunroom and just 2% had a French balcony. As an indicator of good housing design quality, ideally these outdoor spaces should be minimum 4 m² so that they can support versatile use. The four representative micro-homes appeared to meet this criterion (Table 2 [6]); however, the balconies were often compromised by open door swings, reducing their use. A visual connection to the outdoor space from inside is also usually met as an indicator of good housing design quality (Table 2, [2], though the quality of views is unknown.

Type A and B apartments: Adjustability

Clearly, the possibilities of spatial divisions in a small apartment are inevitably limited. Hence, there is limited potential in micro-homes to achieve configurational adjustability that the dwellers themselves can create in the space. This was especially the case in the type A tunnel-like micro-homes, due to their reliance on a single window, narrow width and long depth. This made it infeasible to create a separate sleeping area, as this created a space without access to a window or ventilation, and it also created a long corridor and took up a large proportion of the small space, as illustrated in Figure 11. However, there was potential in B-type micro-homes that were divided into two spaces so that adjustability aspects could be incorporated in principle. For example, the space could be restored from two rooms into one open space or vice versa, allowing residents to make changes to suit changing needs over time (see Figure 12). Nevertheless, the services, wall design and flooring material were not designed to support this change. Moreover, Type B apartments only represented 12% of the studied sample, so this adaptability was only possible in a small number of units. See Table 2, [8].

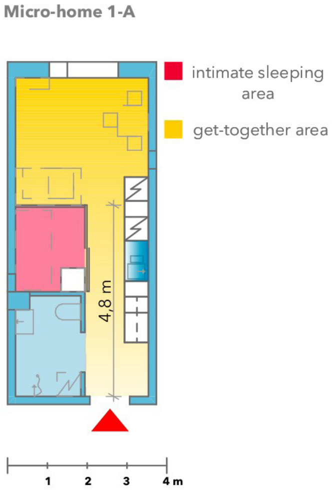

Figure 11
The elongated space of Type 1-A prevented separation of the intimate sleeping area. The narrow and poorly furnishable and usable hallway of the apartment was already long, and the division of space would prolong it even further. The intimate space would also not receive natural light and was not naturally ventilated.

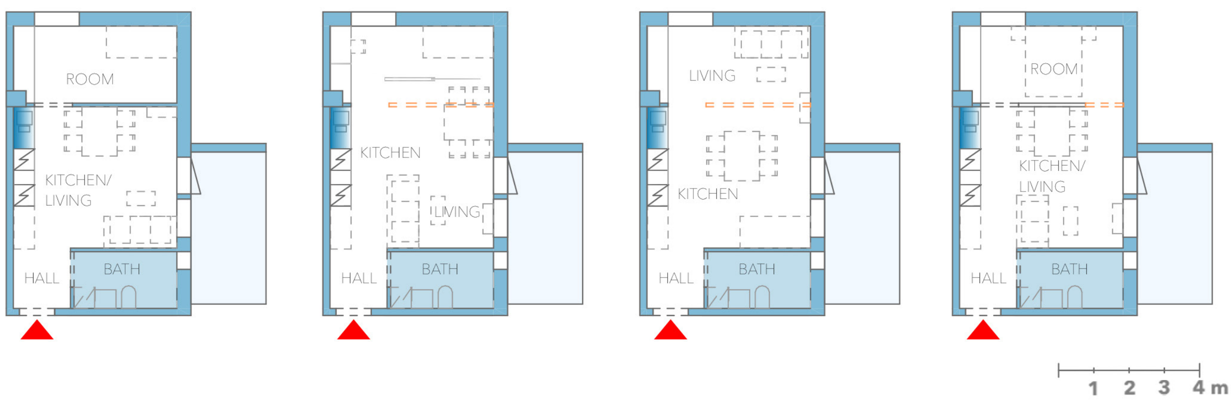

Figure 12
Type 1-B apartment floor plan, indicating that spatial adaptability is possible due to its larger size and having more than one window in several directions. The existing floor plan is on the left, with some alternative floor plans suggested; changes marked in red dotted lines. When the apartment was divided into separate spaces, its furnishing was limited.

Type A and B apartments: Dwelling divisibility (or connectivity)

The splitting of a dwelling into a larger and smaller unit (or the connecting of several smaller units into a larger dwelling) is a highly relevant adaptability design principle for micro-homes. This requires easy connections to be made between units such as the design and construction of noise-compatible partitions between spaces that are not structural, to allow for future "division" or "merging" of units. Of the 60-building sample, only two developments (one in Espoo and one in Vantaa) had purposefully designed some 3-bedroom apartments, where 1 micro-home could be added to create a 4-bedroom larger apartment, or divided from a 4-bedroom into a 3-bedroom home plus a micro-home – as illustrated in Figure 13. While this represented best practice, such principles are ideally applied to more units (they represented only 0.25% of the studied sample) and not only to already large apartments of over 100 m² (creating even larger units), see Table 2, [9].

Figure 13
The connectivity/divisibility principle in a Vantaa housing block included in the studied sample – reproduced from marketing material.

Despite only two developments purposely incorporating this adaptability level in the sample, a total of 62% of micro-homes in the studied sample could be relatively easily combined in theory with other units, if they had been intentionally designed for this. For example, 38 % (or around 610) of the studied micro-homes could be relatively easily combined with other micro-homes, if allowed for at the design stage, by the use of non-structural partitions in between units. These principles were studied in the two case studies, exploring possible easy combinations (despite not being designed for it), see Figure 14 to 16. In the larger studied sample, 15% of micro-homes could also be combined with 1-bedroom units, 6% with 2 bedroom and 3% with 3-bedroom units. Only combinations that were “easy” to make with few adaptations were included (e.g., no need for changes to services).

Nevertheless, the figures highlight that combining deep-plan A-type units were still limited and problematic in use, due to their compro-

Figure 14
Illustration of the connectivity of two small Type A micro-homes into one larger 1-bedroom unit; note that a large part of the indoor space will remain poorly lit due to the deep-plan design. On the left-hand side is the original plan with two micro-homes, and in the middle is the connection of the micro-homes into a 1-bedroom apartment without disconnection of bathroom or kitchen services; the right-most image indicates more disruptive works to disconnect services in one of the units to increase usability.

mised daylight limiting the optimisation of those spaces. Indeed, combining two deep plan dwellings simply creates a larger dwelling that is still problematically deep-plan. In these instances, apartments of almost 49.5 to 64.5 m² could be formed, and the two windows of the combined areas in most cases faced the same direction. (Figure 14). Similarly, when combining an A-type unit with a larger B-Type unit, poor daylighting was carried over from the A-type unit in the larger combined apartment – as illustrated in Figure 15. On the other hand, combining an A-type tunnel-like unit with a dual-aspect B-type unit also highlighted the versatility of a well daylit apartment: it could be combined as a 1-bedroom, a 1-bedroom with a study alcove or a 2-bedroom apartment (albeit with a small second bedroom alcove), see Figure 16.

Connectivity principles do require a change of building structure and potential capping of kitchen services; for example, one of the shower rooms could be turned into storage or a walk-in wardrobe – see illustrations in Figures 14, 15 and 16.

Figure 15
Illustration of the connectivity of a micro-home (A-Type) with a B-type micro-home, creating one larger 1-bedroom unit; note that a large part of the indoor space will remain poorly lit due to the deep-plan design of especially the A-Type micro-home. On the left-hand side is the original plan with two micro-homes, and in the middle is the connection of the micro-homes into a 1-bedroom apartment without disconnection of services; the right-most image indicates disconnection of services.

Figure 16
Illustration of the connectivity of a small Type A micro-home with a B-type micro-home that has the dual aspect to create one larger 1 bedroom, or 2-bedroom unit of 57 m²; note that a large part of the indoor space will remain poorly lit due to the deep-plan design of the original A-Type unit. On the left-hand side is the original plan with two micro-homes, and in the top middle is the connection of the micro-homes into a 2-bedroom apartment without disconnection of services (and 1-bedroom in the bottom-middle); the right-most image indicates disconnection of services for the 2-bedroom or 2-bedroom configuration (top right or bottom right respectively). The dual-aspect nature highlights the increased adaptability potential.

Summary

Table 2 maps the evaluation of the Type-A and B micro-homes against the earlier identified housing design quality indicators (Table 1). The prevalence of micro-homes (40% of the sample) did not provide sufficient apartment choice, which is an important aspect of good housing design quality (see Table 2, [4]). Most of the other indicators were also not met in the majority of the micro-homes in the sample (shaded red); this was especially pronounced in the tunnel-like type-A units. This highlights that the majority of the current micro-home production in this sample did not meet good housing design quality, nor were they able to adapt to changing situations and circumstances, which is not sustainable. The only standard met in the majority – but not all – of the studied micro-homes was access to an adequate private outdoor space, see Table 2 [6].

After evaluation of the adaptability principles, it became clear that the current Finnish micro-homes were, in principle, poorly able to accommodate changes over time. Especially the tunnel Type-A micro-home, the majority (79%) of the production in the sample, did not allow various furnishing options, nor met basic adaptability design principles to accommodate the needs of diverse users over time. Moreover, due to their plan depths and single-aspect nature, daylighting and indoor environmental and spatial quality were significantly compromised. Given that Type-A is the prevalent micro-home design in the sample, it raises questions about the long-term quality and sustainability of the Finnish housing stock.

Discussion

Comparison to other countries

Housing construction in Finland has changed rapidly during the last two decades (SAFA, 2020). Not only has the average size of the whole housing stock shrunk, but also the share of micro-homes has increased. Finland has a notably higher number of micro-homes compared to some other European countries, for which statistics could be obtained. For example, in Denmark just 7.5% of all urban apartments are below 50 m^2, of which 2% is student housing (StatBank). In the UK, overall new-built micro-homes have remained steady at 9–14% (National Statistics UK, 2020). The number of new-built micro-homes nearly doubled between 2010 to 2016 from 3513 to 7809 in the UK (Statista, 2020), and approximately 3% (1000–2000 units) of all new-built homes in London are micro-homes (King's College London, 2020). However, these are modest numbers compared to Finland, which has only one tenth of the population of the UK. Finally, in the Stockholm region, 25% of the new housing production is reported to be micro-homes, with 76% that are sized 35 m^2 or less (Secretary office for Architecture, 2019). While the statistics are hard to compare exactly (for example Denmark's reported floor areas include a proportion of communal areas and private external space), they highlight that the Finnish production of new micro-homes is unprecedented, unsustainably high and very worrying.

Improved housing design quality is needed

Three main problems in the tunnel-type A micro-homes were identified (i.e., 79% of the sample). Firstly, it was problematic to arrange different privacy levels or uses as an unusable long corridor was created, and when divided with walls, a dark private room was produced that could not be properly daylit or ventilated. Secondly, there was a major problem with natural lighting, due to its elongated deep-plan, leaving much of the unit with poor natural lighting. Moreover, the location of enclosed balconies in front of the only available window further reduced access to daylight and sunlight in the year-round living spaces. Thirdly, the major issue in relation to the required sustainability of the construction (set in Finnish law since 2000), showed that adaptability had not been considered in the design of micro-homes; only two of 60 developments had purposively considered divisibility or connectivity for 10 units in the blocks (i.e., only 0.25% of the studied sample). Yet this could be possible for 62% of all micro-homes if designed for it. Nevertheless, even if the merging of micro-homes or the dividing of larger units was technically possible, the combined spaces remained poorly usable and poorly daylit, due to

Table 2
Investigation of the micro-home sample using housing design quality indicators at the apartment scale as a checklist. Use of a "traffic light" system to indicate if an indicator is met (green), partially met (orange), or not met (red) for all or the majority of units.

Housing Quality Indicators – apartment scale		**Investigation of micro-homes (based on representative sample)**	
Design Quality	**Recommendations**	**A type**	**B type**
[1] Natural lighting	Natural light in at least two directions; daylight factor of min. 2% (ideally 5%) in living spaces (Lelyveld & Livingstone, 2018)	Not met in 90% of units which are single-aspect and deep-plan (> 2x the ceiling height). Kitchens are located on an internal wall and have no access to a window.	Only 22% of the apartments were dual-aspect and, while the depths of apartments varied, typically they were shallow plans when single-aspect. Some kitchens were located on an external wall and have access to a window. See Fig. 9.
[2] Connection to outdoors	Number and quality of views. Windows in as many directions as possible. Kitchen should be located on an external wall and have at least one openable window to ensure good ventilation and lighting.	Quality of views and views of the sky could not be evaluated due to lack of information.	
[3] Apartment entrance	Niches that can be used as work, play or storage areas; width of at least 1.6 to 1.8m wide, naturally lit and 2.4m deep.	The entrance area is not naturally lit, can only be used for storage and not for other uses. The average daylight factors in typical cases 1-A and 1-B are around 0.1-0.2%, indicating reliance on artificial lighting. See Fig. 7 to 9.	
[4] Choice of apartment	No type of apartment should be represented by more than 30%; small apartments with 2 rooms are grouped as 'one type'. Avoid: one type of apartment > 70%.	Not met in the sample of current Finnish housing production. There are 71% of units with 2 rooms or fewer, with micro-homes making up 40% alone.	
[5] Spacious living	Separate areas for socialising away from private rooms.	No separation of communal and intimate spaces possible due to the small size, spatial form and single-aspect. See Fig. 6, 8 and 11.	In some cases, separate areas are possible (see e.g., Type 2-A, 2-B). Nevertheless, the living area remained too small.
[6] Private open outdoor space	size of $4m^2$/room and facing towards the sun.	61% of units had a balcony that supports some versatile use, though 2% had no balcony and 37% a French balcony only. Orientation not evaluated.	97% of units had a balcony that supports versatile use; orientation not evaluated.
[7] Furnishability	Choice to where dining table and beds are positioned in a room, i.e., more than one position is possible.	Only one position is possible without compromising the use of the apartment, e.g., moving the bed is possible but then window or kitchen cabinets opening is compromised. See Fig. 6.	Usually not met; the small total area challenges the possibilities for furnishing. In some situations, there are several furnishing options in living areas in the slightly larger units.
[8] Adjustability (Adaptable dwelling)	The dwellers themselves can reconfigure the space, without the need to change the long-lasting parts of buildings.	No adjustability potential as the small size, spatial form and single-aspect do not support further division (see Fig. 11.)	Generally, there is potential to open (and re-divide) the space, but this is not planned for (e.g., inner wall is not adaptive; flooring does not continue under the wall, etc. (see Fig.12). In single-aspect units, adjustability depends on window location.
[9] Divisibility (or connectivity)	Where more than two thirds of apartments can easily change in size.	Not met; at present only 2 of the 60 blocks had some units intentionally designed to be combined with larger units. However, a total of 62% of micro-homes in the sample could be relatively easily combined in theory with other units, if they had been designed for this. Nevertheless, combining deep-plan units still limited their use (i.e. lack of daylight in deep-plans limits the use of those spaces).	

the deep and narrow plan spaces. Finally, apartments representing the B-type would be best suited as studios that the residents could divide in one way or another.

The need to diversify the current urban housing typology in Finland

To increase housing diversification, differently sized and flexibly designed housing units are required, as opposed to the current large number of small and unadaptable units in the current Finnish housing production studied here. A different constellation of apartment sizes would be needed to support divisibility principles, as well as connectivity principles to support long-term sustainability of the housing stock.

The connectivity concept may, however, be hard to achieve in reality: depending on logistics, another unit may never be available to connect to, when needed. Furthermore, instead of designing units to be connected in the future, design for divisibility can be more useful, i.e., designing a large "family" apartment that can be divided into smaller units, creating micro-homes if and when future needs require it by that family. This strategy requires not only two exterior doors to a large apartment, but also a suitable apartment size and shape, including suitable building services locations.

This current lack of housing diversity and its lack of adaptability will be "locked-in" for decades to come, and is not aligned with the Finnish Land Use and Building Act, which has required sustainable housing solutions since 2000.

Lessons to support better housing design in the future

The pressure to provide urban housing often leads to maximised land development (i.e., an increase in number of units per site and per building) at the expense of housing design quality (Punter, 2010). The prevalence of the tunnel-like Type-A micro-home in the studied sample was made possible by today's prevalent Finnish central corridor buildings that led to repetitive rows of single-aspect units in the middle of the block; this planning type should be challenged through more versatile design. More slender building blocks would enable shallower plan and dual aspects units with windows on two sides, supporting good housing design quality, including adaptability. However, as Saarimaa & Pelsmakers (2020) noted, the building block configuration is often determined by the city plan, and this highlights the inter-relationship between the urban plan, building typology and the implications for apartment plan design.

The possibility to develop to the limits of the city plan has enabled the creation of deep-plan building types, which is connected to a significant number of tunnel-like micro dwellings (Type-A). If – as is the case at present in Finland – there are no other housing design quality criteria attached to the permissible building rights set out in the urban plan, developers may simply maximise the permissible building rights and create bulky buildings with many deep-plan, problematic micro-homes. It will be important to balance the city's densification and the economic justification (affordability, profitability) of micro-homes with a satisfactory and sustainable living environment for residents - this is highlighted for further research.

Conclusion

Low birth rates combined with the ageing of the population have raised the urgency of the housing question for solo dwellers. While for some dwellers, for a short period in one's life, a micro-home might offer sufficient private space (Clinton, 2018), the needs, desires and actual choices of solo dwellers (Tervo, 2021), as well as the study of the design of micro-homes intended to meet their needs, should continue to be investigated. This article uniquely investigated a large sample of 60 current residential buildings in Finland's largest six cities and studied four representative micro-homes in two blocks in more depth. Nine generally accepted housing design quality indicators were used to investigate, compare and visualise different housing design quality aspects of micro-homes in more detail.

Based on our studied sample, the first main outcome of the research highlighted the lack of housing design quality in the construction of contemporary micro-homes in Finland. It clearly demonstrated how fewer micro-homes and more spacious units were required to fulfil the needs of sustainable construction. Of the sample of 4007 dwellings, 40% (or 1610) units were micro-homes of 29.4 m^2 average size. One bed-room apartments (31%) were on average 48.8 m^2. Both types of new housing were below the national averages (Official Statistics of Finland, 2018), indicating a change towards smaller and smaller units in the current housing production. Any gains from long term housing policies (established during the creation of the welfare state to provide decent housing space) can be lost in just a few years if this new type of construction continues.

The second main outcome of our studied sample relates to the actual usability of the micro-homes. Our research showed how the majority of the current construction of micro-homes almost completely dismissed good housing design principles. As many as 79% of the analysed micro-homes represented Type-A, tunnel-like micro-homes that neglected eight of the nine recommended housing design principles. Only one criterion, i.e., private outdoor space, was partially met in Type-A units. Even in the slightly larger Type-B apartments (12% of the sample), three out of nine criteria were not met, four criteria were only partially met for a minority of units, while the criterion for external space provision was met in the majority of units.

Thirdly, our study demonstrated how the use of the generally accepted housing design quality indicators to systematically investigate and visualise the micro-homes' characteristics could be used as a transferable checklist method, when investigating and comparing the housing design quality of micro-homes.

Based on the analysis in this article, the current Finnish construction of micro-homes is simply not sustainable, even if there was potential in larger and undivided B-types. Our study highlighted that the worrying prevalence of micro-homes and their poor design in the current Finnish housing production needs urgent scrutiny. The prevalence and poor housing design quality of the current production of micro-homes in Finland creates a worrying lock-in of small units that do not meet solo dwellers' needs, let alone other residents' needs for working from home, ageing at home, raising a child and other life situations. The study highlighted that ignoring good housing design principles in the current housing production prevents sustainable and decent housing, compromising residents' health and well-being, now and in the future. If we cannot clearly address the weaknesses of the current construction trend and show and articulate the lack of good design principles in micro-homes, we enable macro mistakes to happen in a housing stock that was intended to remain for the next hundred years.

Acknowledgements

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