Tampere University

TAPIO KAASALAINEN

Potential for Ageing at Home in the Finnish Apartment Building Stock

A Spatial Perspective on Renovation

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ACADEMIC DISSERTATION
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Nokia, December 2020
Tapio Kaasalainen

ABSTRACT

Populations around the world are ageing rapidly, owing largely to increased longevity. This development, while positive in itself, sets great demands for providing suitable housing—especially when combined with the nearly universally embraced goal of ageing at home. There is a growing need for accessible dwellings, which the similarly ageing housing stocks that are often disproportionately inhabited by old residents fail to meet. Furthermore, with the rising proportion of the oldest old and widespread favor of deinstitutionalization, assisted living is increasingly needed to care for those in poorest health. At the same time, the increasing urbanization in many countries makes new construction a largely infeasible solution to this joint challenge of population and building stock ageing, both ecologically and economically. Instead, focus is more and more shifting from new construction to managing the existing stock through renovation.

The general need for building adaptations to support ageing at home is well acknowledged, as are the potential benefits of various adaptations. Notably lacking, however, is research on the spatial renovation measures that are on the one hand typically needed, and on the other hand feasible to implement in those typical cases. The current research addresses this gap by examining Finnish mass housing from the 1970s, which as in many other countries forms a major part of the current overall dwelling stock and houses a similarly major part of the ageing population. Corresponding to the main forms of housing for older people in Finland, the existing stock is assessed from the specific perspectives of suitability and adaptability for independent housing, and adaptability into assisted living group homes.

Methodologically the dissertation is based on taking a typological approach to building stock research, through which typical properties of the stock are assessed through a reduced set of theoretical cases. As the foundation for the assessment, a quantitative examination of a representative sample of existing apartment buildings is conducted to determine the recurring spatial properties in the stock. This part produces a typological categorization of spatial layouts based on network theory with complementary information on dimensions and structural systems.

Addressing the perspective of independent housing for older people, the above is first followed by a literature informed, research by design -based multi-case study. Through this the common changes required in typical apartments, and the options available for conducting them, are determined. Next, a quantitative examination similar to the earlier one is aimed at existing assisted living group homes, together with a complementary literature review, identifying their typical spatial characteristics. The resulting information combined with that on the spatial properties of existing apartment buildings is then used in a quantitative multi-case study to assess the potential for repurposing apartment building floors into assisted living group homes for older people.

The results of the research indicate that the Finnish mass housing stock holds vast potential for housing the ageing population, and that renovation constitutes a viable complement and alternative to new construction. Through different degrees of adaptation, it is typically spatially feasible to address the changing housing needs ranging from fully independent apartments to intensive forms of assisted living. For independent housing, relatively minor changes will often suffice to reach significant improvements. For assisted living, more spacious designs than are common in new construction will have to be accepted, which is arguably advisable regardless due to the often extreme compactness found in recent production.

The dissertation contributes to the field of building stock research by developing and presenting tested typological methods for assessing renovation potential and refining this potential into generalizable design models. While the direct findings discussed above pertain primarily to the Finnish context, the methods introduced can be applied to any sufficiently repetitive stock. Furthermore, they are not tied to the specific use case of housing for older people the current research focused on. In addition to the aforementioned design models, the practical implications of the research mainly concern informed decision making in utilizing the existing buildings. The results presented support acknowledging and examining the stock as not only what it is, but also as what it could be. Through the combination of quantitative data and concrete, tested designs, this contribution covers a wide range of perspectives from national policy making to individual homeowners.

TIIVISTELMÄ

Keskimääräisen eliniän noustessa väestön voimakas ikääntyminen on lähes maailmanlaajuinen ilmiö. Tästä sinänsä selkeän positiivisesta kehityksestä aiheutuu suuria haasteita asuntotarjonnalle—erityisesti yhdistettynä laajalti omaksuttuun kotona asumisen tavoitteeseen. Tarvitaan yhä enemmän esteettömiä asuntoja. Samaan aikaan usein juuri ikääntyneet asuvat vanhimmissa asunnoissa, jotka eivät vastaa heidän tarpeitaan. Lisäksi kaikkein vanhimpien ikäluokkien kasvu yhdistettynä laitoshoidon vähentämiseen lisää palveluasumisen tarvetta. Kaupungistumisen myötä edeltäviin haasteisiin vastaaminen uudisrakentamisella on yhä useammin epärealistista sekä ekologisesti että taloudellisesti niin väestön kuin rakennuskannankin ikääntymisen ollessa voimakkainta taantuvilla alueilla. Tämän seurauksena huomio kiinnittyy alati enemmän olemassa olevan rakennuskannan hyödyntämiseen ja sen edellyttämiin korjaustoimenpiteisiin.

Tarve kotona asumista tukeville korjaustoimenpiteille on laajalti tunnistettu, kuten erilaisten toimenpiteiden edutkin. Tutkimustietoa kuitenkin puuttuu siitä, millaisia tilallisia muutoksia tyypillisesti tarvitaan ja toisaalta, miten toteutettavissa nämä ovat kyseisissä tyypillisissä tilanteissa. Tämä tutkimus tarkastelee suomalaista 1970-luvun kerrostalotuotantoa, joka useiden muiden maiden tavoin muodostaa suuren osan nykyisestä rakennuskannasta ja jossa asuu niin ikään suuri osa ikääntyneestä väestöstä. Suomen vallitsevia ikääntyneiden asumismuotoja vastaavasti olemassa olevan rakennuskannan tarkastelun näkökulmana on soveltuvuus ja muokattavuus ikääntyneiden itsenäiseen asumiseen sekä ryhmäkotimuotoiseen tehostettuun palveluasumiseen.

Metodologisesti tutkimus perustuu typologiseen rakennuskantatutkimukseen. Rakennuskannan tarkasteluun käytetään rajattua joukkoa teoreettisia case-kohteita, jotka muodostetaan selvittämällä laajasta otoksesta todellisia kohteita tyypilliset, toistuvat tilalliset ominaisuudet. Tämän myötä muodostetaan verkkoteoriaan perustuva tilajärjestelyjen typologia, johon sisältyy myös täydentävää tietoa mitoituksesta ja rakenteellisista ratkaisuista.

Edeltävän pohjalta käsitellään ensiksi ikääntyneiden itsenäisen asumisen mahdollisuuksia. Tämä osio muodostuu kirjallisuuteen tukeutuvasta, research by design -periaattein toteutetusta monitapaustutkimuksesta, jolla selvitetään tyypillisten asuntojen yleiset muutostarpeet sekä mahdollisuudet näiden muutosten toteuttamiseksi. Seuraavaksi tarkastelu suunnataan tehostetun palveluasumisen ryhmäkoteihin. Aiempaa asuinkerrostaloihin kohdistunutta selvitystä vastaavasti joukosta olemassa olevia tehostetun palveluasumisen kohteita määritetään tyypilliset tilaratkaisut. Lopulta olemassa olevien kohteiden tilaratkaisuja verrataan aiemmin kartoitettuihin asuinkerrostaloihin määrällisessä monitapaustarkastelussa näiden käyttötarkoituksenmuutospotentiaalin määrittämiseksi.

Tutkimuksen perusteella Suomen kerrostalokannassa on suurta potentiaalia ikääntyneiden asumisen haasteisiin vastaamiseksi. Korjausrakentaminen on tästäkin näkökulmasta varteenotettava vaihtoehto ja täydentävä keino uudisrakentamiselle. Eriasteisin muutostoimin on useimmiten mahdollista vastata muuttuviin asumisen tarpeisiin itsenäisestä, esteettömästä asumisesta aina tehostettuun palveluasumiseen asti. Itsenäisen asumisen osalta jo varsin pienilläkin muutostoimilla voidaan saavuttaa merkittäviä parannuksia. Käyttötarkoituksenmuutoksissa tehostettuun palveluasumiseen on pääosin hyväksyttävä nykyistä uudisrakentamisen käytäntöä väljempi tilamitoitus. Huomioiden uudistuotannon usein äärimmilleen viety kompaktius, voi kyseistä suuntausta pitää suositeltavana joka tapauksessa.

Tämä väitöstyö edistää rakennuskantojen tutkimusta kehittämällä, testaamalla ja esittämällä typologisen tarkastelumetodin, jolla voidaan arvioida rakennusten muutospotentiaalia ja edelleen jalostaa tämä potentiaali yleistettäviksi suunnittelumalleiksi. Tässä tutkimuksessa tehdyt havainnot rakennusten piirteistä ja käytettävyydestä koskevat ensisijaisesti Suomen kontekstia, mutta käytettyjä metodeja voidaan soveltaa mihin tahansa vastaavan itseään toistavaan rakennuskantaan. Ne eivät myöskään ole sidottuja tässä tutkimuksessa käsiteltyyn ikääntyneiden asumisen aihepiiriin. Edellä mainittujen suunnittelumallien lisäksi tutkimuksen käytännön vaikuttavuus muodostuu ensisijaisesti tietopohjaisen päätöksenteon mahdollistamisesta olemassa olevien rakennusten hyödyntämiseen liittyen. Saavutetut tulokset ohjaavat huomioimaan rakennuskannan tarkastelussa paitsi mitä rakennukset ovat, myös mitä ne voisivat olla. Yhtäältä laajan aineiston määrällisen tarkastelun ja toisaalta konkreettisten, testattujen suunnittelumallien myötä tutkimuskokonaisuus kattaa laajan kirjon näkökulmia ja toimijoita valtiotason päätöksenteosta yksittäisiin asunnon omistajiin.

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GLOSSARY

Note: the use of terminology related to housing for older people varies greatly between and even within countries, as do the actual implementations. Similarly, there is no established official definition for when a renovation action becomes something more significant than refurbishment. Thus, while the definitions listed below are used consistently throughout this dissertation, their use may differ from some other sources.

Ageing at home Living in an apartment or a house that is not in an institutional facility, i.e. not a nursing home or a hospital. In Finnish policy everything up to and including assisted living in intensive sheltered housing counts as living at home when the resident rents or owns their dwelling (STM, 2017a, p. 15).

Ageing in place Often used interchangeably with 'Ageing at home'. Emphasizes not having to move from one's current home.

Assisted living A housing arrangement where the resident has a permanent residence with services for assisted daily living available (cleaning, bathing, meal service etc.).

Elderly (people) See 'Older people'. The term 'elderly' has negative connotations of e.g. frailty and lack of ability (Avers et al., 2011; Falconer and O'Neill, 2007). Consequently the term is avoided in this dissertation, although some of the included publications do use it. If these connotations are important for context, such as may be the case with assisted living, they are noted separately.

Group home (unit)	A form of assisted living, usually intensive sheltered housing, where a group of small apartments share directly accessible common areas such as a living room or a kitchen. There can be, and often are, multiple group home units in a single assisted living facility. There are also often multiple units even on the same floor, but these typically operate independently aside from possibly sharing some specific spaces.
Habitable room	Living rooms, bedrooms, kitchens etc. A room inside a dwelling that is primarily meant for continuous residential use. Does not include halls, corridors, bathrooms, or equivalent spaces. In Finnish law habitable rooms have certain requirements for e.g. height and window area. (A1008/2017.)
Independent housing	Housing that is a regular dwelling and not part of an assisted living facility, i.e. not sheltered housing nor institutional care. The resident may still receive visiting home care services.
Institutional care	Continuous, around the clock care in a nursing home, health centre or a hospital.
Intensive sheltered housing	A form of assisted living where staff is available around the clock. In Finland typically arranged as a group home.
Living at home	See 'ageing at home'.
Nursing home	A form of institutional care. Functionally similar to intensive sheltered housing, with the distinction that the residents do not rent or own their apartments or rooms.
Older people	People at least 65 years of age. Depending on the context may also include younger people with similar needs to the group of older people being discussed.
Oldest old	People at least 85 years of age. Usually implies increased health issues and/or care needs compared to 'older people'.

Ordinary sheltered housing	A form of assisted living where staff is typically available only during the day. Apartments are usually not part of a group home, although they often have access to more common areas than regular housing.
Refurbishment	Renovation without any significant changes to use.
Renovation	An act of construction which modifies or restores a space, an apartment, or a building to some degree, with or without changes to use.
Repurposing	Renovation which significantly changes the use of a building or (a) space(s) in it.
Senior housing	Independent housing aimed at older people, typically with a certain minimum age for at least one resident of each household.
Slab block	A (residential) building with multiple, separate stairwells. In this dissertation the definition also includes single stairwell buildings which only have windows on two opposite sides and could thus be duplicated adjacent to each other to form a multi-stairwell slab block.
Tower block	A (residential) building with a single stairwell. In contrast to a slab block, a tower block cannot be duplicated to form a multi-stairwell slab block.
Unit	See 'group home (unit)'. In this dissertation units in the sense of a single dwelling are referred to as apartments regardless of whether they are in a group home or not.

ORIGINAL PUBLICATIONS

Article I Kaasalainen, T. & Huuhka, S. (2020). **Existing apartment buildings as a spatial reserve for assisted living.** International Journal of Building Pathology and Adaptation, 38(5), 753–769. doi: 10.1108/ijbpa-02-2020-0015

Article II Kaasalainen, T. & Huuhka, S. (2016). **Homogenous homes of Finland: 'standard' flats in non-standardized blocks.** Building Research and Information, 44(3), 229–247. doi: 10.1080/09613218.2015.1055168

Article III Kaasalainen, T. & Huuhka, S. (2016). **Accessibility improvement models for typical flats: mass-customizable design for individual circumstances.** Journal of Housing for the Elderly, 30(3), 271–294. doi: 10.1080/02763893.2016.1198739

Article IV Huuhka, S., Kaasalainen, T., Hakanen, J. H. & Lahdensivu, J. (2015). **Reusing concrete panels from buildings for building: potential in Finnish 1970s mass housing.** Resources, Conservation & Recycling, 101, 105–121. doi: 10.1016/j.resconrec.2015.05.017

AUTHOR'S CONTRIBUTION

In **article I**, I planned the research/paper design and handled collecting, processing, and analyzing the data. I participated in writing section *1. Introduction*, wrote all of sections *2. Materials and methods* and *3. Results*, and most of section *4. Concluding discussion*.

In **article II**, I participated in planning the paper structure and handled collecting (with colleagues), processing, and analyzing the data. I wrote most of the sections *Research material and methods*, *Typology of flats* (results), and *Discussion*.

In **article III**, the design of the research/paper was conducted in equal collaboration. I handled collecting (with colleagues), processing, and analyzing the data, including drafting the accessibility improvement models. I participated in writing the sections *Introduction* and *Conclusions*, and wrote most of the other sections.

In **article IV**, I participated in collecting and processing the data and wrote section *5.1. Difference between public-funded and privately financed housing production*.

Articles II and **IV** have been previously included in the following dissertation:

> Huuhka, S. (2016). *Building 'Post-Growth': Quantifying and Characterizing Resources in the Building Stock*. Tampere University of Technology, Publication Vol. 1414. Tampere: Tampere University of Technology.

1. INTRODUCTION

Populations around the world are ageing rapidly. By the year 2050 the number of people aged 65 or older is projected to more than double globally from approximately 700 million to 1550 million. An even greater increase is expected to happen in the proportion of people aged 80 or older, which will approximately triple. (United Nations, 2020, pp. 5–6.) This development is especially rapid in Western Europe (Rodrigues et al., 2012, p. 18). Looking further forward, this global ageing is expected to last, though at a somewhat reducing pace, for at least the ongoing century (Lutz et al., 2008). Though behind East and South-East Asia in absolute number of people, the most aged populations in terms of the proportion of people 65 or older are found in Europe, where within the European Union their share is 20.6%—projected to increase to 29.3% by the year 2050 (Eurostat, 2020; United Nations, 2020, p. 7). Focusing the framing further, at the moment 22.3% of the Finnish population is aged 65 or older—by 2050 the estimated figure is 27.5%, and by 2070 31.0% (Eurostat, 2020).

While the increased longevity discussed above is indicative of great advances in many areas such as public health and social equality, it also brings great challenges for sustainable development (United Nations, 2020, p. 1). An important one is housing the ageing population in a manner that is at the same time socially responsible on all levels from a single individual upwards as well as economically and ecologically feasible on all the same scales. Viewing sustainability through the framework of the United Nations Sustainable Development Goals (United Nations, 2015), housing for older people is directly connected to at least the following: promoting well-being for all at all ages (3); reducing inequality (10); making cities and human settlements inclusive, resilient and sustainable (11); and ensuring sustainable consumption patterns (12). Achieving these goals during the ongoing demographic shift poses significant challenges related to e.g. the availability of apartments that are accessible and suitably sized for older people, an increasing number of whom live alone, especially in the Nordic countries (Reher and Requena, 2018, p. 449).

Along with its residents, the building stock itself is also ageing. Nearly a fifth (18.7%) of all Finnish dwellings are located in multi-storey apartment buildings from the 1960s and 1970s (Official Statistics of Finland, 2019a). Including the 1980s raises the figure to a quarter (24.2%). These buildings utilized prefabricated concrete panel construction and were typically mass produced as large housing area developments (see example in figure 1). Currently this building stock ageing is showing as an ever increasing need for considerable renovations (Hietala et al., 2015, p. 21; Riihimäki et al., 2019, p. 17). Like population ageing, building stock ageing is also a trend not restricted to Finland. Maintaining and updating existing housing, as opposed to a primary focus on new construction, has increased in importance in many European countries (Thomsen and Van Der Flier, 2009, p. 649). This applies especially to the large post-war housing estates constructed in the 1960s and 1970s, which like in Finland are now largely in need of renovation for reasons ranging from structural and technical issues to spatial unsuitability (Baldwin Hess et al., 2018, p. 7; Meijer et al., 2009, pp. 540–541; Thomsen and Van Der Flier, 2009, pp. 649–650; Wassenberg et al., 2004). These estates exist in varying but consistently significant amounts throughout Europe, in for example Denmark, Germany, Hungary, Netherlands, Poland, Slovakia, Slovenia, Sweden, and Ukraine (Bundesministerium für Raumordnung, 1992; Slaug et al., 2020; Stenberg, 2013; Turkington et al., 2004; Wojciechowska, 2019).

Figure 1. Typical Finnish post-war apartment buildings. Aerial photograph from Pihlajisto, Helsinki, 1978. Photographer: SKY-FOTO Möller (1978).

In the coming decades, increases in longevity will cause an increase in the number of especially the oldest old, usually defined as people 85+ years of age (von Humboldt and Leal, 2015, p. 156), in Finland like in many other countries (Eurostat, 2020). Especially as household sizes decrease in general, more and more of these people will be living alone (Lith, 2018, p. 9; Rodrigues et al., 2012; Terämä et al., 2016). Although it has been predicted that in the future the narrowing of the gap in life expectancies for women and men in many countries will actually reduce the share of older people living alone through there being fewer long term widows (Martikainen et al., 2016; Rodrigues et al., 2012, p. 26), the proportion of people who don't have a partner to begin with will still increase. Furthermore, even though the causes and mechanisms involved are obviously different, in Finland a pattern of ageing similar to that of the population can also be expected in the apartment stock, if current broad trends regarding construction and demolition continue (see figure 2). Since population ageing outpaces the approximately 1% annual renewal rate of the apartment stock (Meijer et al., 2009, p. 544), this results in an ever increasing share of older people living alone in ever older buildings.

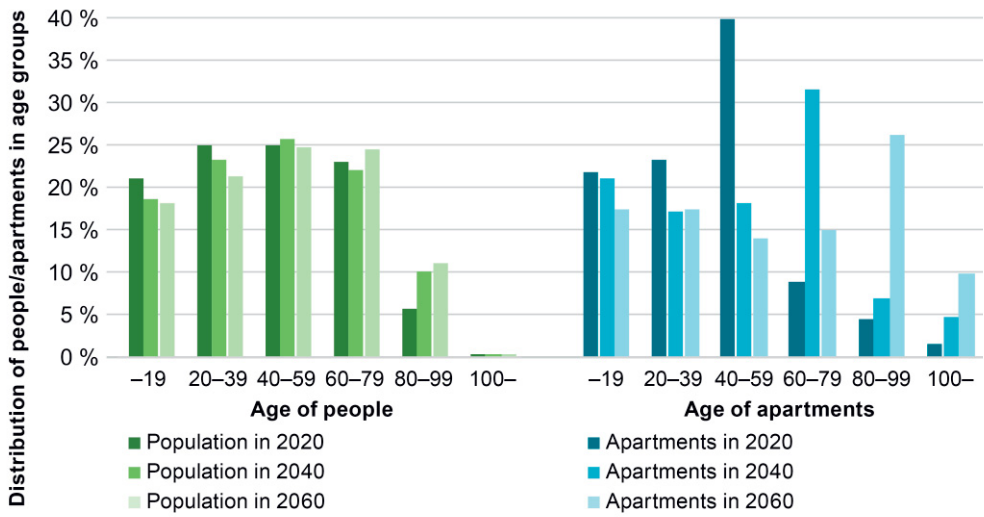


Figure 2. Finnish population and apartment stock in multi-storey blocks by age group in the years 2020, 2040, and 2060. Population development is based on Eurostat's baseline projection (Eurostat, 2020). The initial number of apartments in 2018 is based on Official Statistics of Finland (2019b). Figures for years 2020, 2040 and 2060 are estimated based on figures presented by Huuhka and Lahdensivu on demolition of apartment buildings in different age groups (2014, p. 12, table 8) and the average yearly apartment production during the years 2000–2019 (Official Statistics of Finland, 2020).

It is also notable that the above demographic and building stock developments, although nationwide trends in Finland, are not equally distributed among all geographic areas. Instead, population ageing, building stock ageing, and an increase in single person households are all clearly strongest in suburban housing estates (Helminen et al., 2017, p. 45; Kivi and Nurmi-Koikkalainen, 2007; Lankinen, 1998; Stjernberg, 2019, p. 244). Furthermore, these phenomena appear to be connected so that an increasing number of single person households in these ageing estates are specifically older people living alone (Stjernberg, 2019, pp. 245–246). This is supported by the fact that living in an apartment block is more common among single older people than among those living with a partner (Helminen et al., 2017, p. 43). A disproportionate share of older people also live in dwellings from the 1960s to 1970s (Helminen et al., 2017, p. 45), which was when a major part of these estates were constructed (Stjernberg, 2019, p. 17). Due to the rising old age dependency ratio caused by overall population ageing and low birth rates, in Finland like in many other countries (World Bank, 2019), enabling older people to stay independent as long as possible is paramount for the functioning of the welfare state (Rodrigues et al., 2012, p. 15). As a result, the need for renovations is increasingly driven by the need for accessible apartments that support this independence.

The above developments are also again not limited to Finland, but rather are increasingly occurring throughout Europe (Baldwin Hess et al., 2018, p. 4). For example, Kabisch and Grossmann report the very same demographic shifts in eastern German post-war mass housing (2013, p. 233). In their study of 1960s to 1980s prefabricated concrete panel housing in Tallinn, Kährik and Tammaru (2010, p. 213) showed an age structure and household size distribution not much different from other residential areas, but found that older people are most likely to remain in these estates, which suggests upcoming similar developments. Despite local differences in the specifics of both dwellings and dwellers, there is no doubt that the twin phenomena of building stock ageing and population ageing are an increasingly pressing issue that needs to be addressed as a joint challenge.

1.1. Population ageing and changing needs for housing

Ageing typically brings various difficulties with activities of daily living. Some are due to overall reduced mobility simply making it harder to bathe, cook, or go outside (Chatterji et al., 2015, p. 567; Mackenbach et al., 2005, p. 84; Strandell and Wolff, 2019, p. 50). These are often further compounded by e.g. decline in sense of balance, touch sensitivity, and muscular strength (Pajala, 2012), as well as vision impairment (Loh and Ogle, 2004). Furthermore, the likelihood of cognitive impairment also greatly increases with age (Barbosa et al., 2020, p. 7; Dewey and Prince, 2005, p. 125; Ferreira et al., 2020, pp. 4–5; Murman, 2015; Rodrigues et al., 2012). This adds its own set of challenges related to the above activities (Barbosa et al., 2020, pp. 10–11; Dewey and Prince, 2005, p. 125), and also puts increased emphasis on e.g. easily navigable layouts (Netten, 1989) as well as on clear, consistent use of materials and colors (Pollock and Fuggle, 2013, p. 2). In general, ageing also often comes with worse outcomes from for example falls resulting from an unsuitable living environment (Clegg et al., 2013). Although the duration of one's life spent burdened by physical or cognitive difficulties varies (Chatterji et al., 2015, p. 572; Strandell and Wolff, 2019, p. 50), the sheer numerical increase in the older population means that requirements for housing are changing significantly (Eurostat, 2020). Thus a holistic approach to accessibility is vital for older people to be able to live safely and independently. Although 'home' as a concept is more than just one's dwelling (section 1.1.1), the dwelling is undeniably central to it, especially considering how ageing often narrows down the daily living environment (Oswald and Wahl, 2005).

In addition to the rising need for accessible apartments to support fully independent living, home care for older people is largely prioritized over assisted living and institutional care facilities in Europe, and especially in the Nordic countries (Rodrigues et al., 2012, p. 88; Spasova et al., 2018, p. 14). Thus the apartments are increasingly often not only private residences but also work environments for home care staff. Finally, despite the widely adopted goal of deinstitutionalization (ibid.), assisted living facilities are still required in order to provide sufficient care for those in poorest health. In Finland for example, while institutional care has been eliminated almost entirely, there has been a simultaneous matching increase in the amount of intensive sheltered housing (Official Statistics of Finland, 2019c; THL, 2020; for details see section 1.1.2).

1.1.1. The importance of ageing at home

Ageing at home is a widely embraced policy goal in Europe and even globally (Gadakari et al., 2018, p. 18; Lui et al., 2009, p. 116; Spasova et al., 2018, p. 37). Correspondingly, remaining independent is the main priority when it comes to housing for older people in Finland (L 980/2012, 2012; STM, 2017a), again similarly to many other countries (Rodrigues et al., 2012). Although on a national level—in Finland as widely elsewhere—a major component is of course the cost savings involved compared to institutional care (Spasova et al., 2018), ageing at home is also desired by most older people themselves (Costa-Font et al., 2009; Fänge and Dahlin-Ivanoff, 2008, p. 344; Hakala and Id-Korhonen, 2016, p. 7; Jong et al., 2012). While this could be considered obvious for ageing at home in regular apartments, it is notable that the same preference and benefits also exist for assisted living facilities (Afshar et al., 2017; Kovacic et al., 2015). In Finnish policy everything up to and including assisted living in intensive sheltered housing officially counts as living at home (STM, 2017a, p. 15).

Much of the preference for ageing at home appears to be tied to autonomy, including the ability to make housing related decisions, being as vital to older people as it is to anyone (Andresen and Puggaard, 2008). In fact, in an interview study on the meaning of ageing in place to older people, Wiles et al. (2011, p. 360) found the most important thing for happy ageing to be having choices about one's living arrangements. Correspondingly, maintaining independence and autonomy was noted to be an integral part of one's identity (Wiles et al., 2011, p. 364). Related to the ability to choose, it should be noted that ageing at home is not necessarily the same as ageing in place. Instead, what is important is feeling at home, and 'home' can move with the person (e.g. Aminzadeh et al., 2010, p. 30).

Even though most older people prefer to stay in their current home (Ewen et al., 2014, p. 289; Hakala and Id-Korhonen, 2016, p. 24; Löfqvist et al., 2013, p. 924), the stance is not entirely universal. Some do not mind moving in old age, even to an assisted living facility (Fänge and Dahlin-Ivanoff, 2008, p. 344). Furthermore, staying put is not automatically conducive to wellbeing (Fernández-Carro and Evandrou, 2014, pp. 31–32). Thus it is important to consider that while solutions that support ageing at home enable the current resident to age in place, they can just as well allow providing a suitable apartment for someone moving in from elsewhere. Taking this into account, supporting ageing at home can be considered to provide a wider range of options than focusing singularly on ageing in place. Furthermore, it has been noted that ensuring that the built environment supports ageing at home is not only a benefit to older people. Rather, it has been argued that taking the needs of older people into account promotes lively, high quality environments and correspondingly creates better places for all (e.g. Gilroy, 2008, p. 160).

Regardless of the specific type or location of dwelling, it is clear that the concept of home is not limited to the apartment or house itself, nor even the physical surroundings. Instead, a home is a combination of a physical place, personal meanings, and existing social networks. This is reflected by some of the most recurring themes associated with living at home in research being social inclusion and a sense of belonging. For example, studying the effects of place attachment on the social wellbeing of older adults, Afshar et al. (2017) found a strong positive correlation between the feeling of place attachment and social wellbeing, understood as one's ability to participate in society and feel accepted in it. Following this, a positive effect on psychological wellbeing was noted. Similarly to these findings, in their international literature review on what makes a community age-friendly, Lui et al. (2009, p. 120) found positive social relations, engagement, and inclusion to contribute to wellbeing in old age. Likewise, Vitman and Khalaila (2018, p. 8) found participation in social activities to have a great impact on the quality of life of older people. Reviewing data from the pan-European SHARE survey (Survey of Health, Ageing and Retirement in Europe), Stoeckel and Litwin (2015, p. 156) found social connections to be highly important for well-being in later life, especially in otherwise deprived neighborhoods. Supporting the above notions on the importance of social participation and remaining active, the 80–89 year old people interviewed in Fänge and Dahlin-Ivanoff's (2008, p. 343) study defined their perceived health based on their ability to be active, not based on their diseases and the symptoms of those. Accordingly, the authors highlighted most of all the need for home environments to support this activeness through accessibility, safety, and familiarity (p. 344). This emphasis is supported by Aminzadeh et al. (2010, pp. 29, 33), who also note that the feelings of competence, permanence, and belonging brought by feeling at home, though important for all, are especially vital for people with dementia. Echoing these themes, older people interviewed by Wiles et al. (2011, p. 364) considered ageing in place to support their sense of identity through independence and autonomy. Overall, research on ageing at home makes it obvious that in addition to being personal and potentially mobile, the concept of home is for most people inseparable from the larger context with its personal meanings and social networks (e.g. Wiles et al., 2011). Correspondingly, providing the option to retain this context by choosing one's place of dwelling is essential (Park and Ziegler, 2016, p. 13).

1.1.2. The spectrum of housing for older people

A long standing view of housing for older people has been a continuum where one first moves from independent, possibly single family housing to more communal semi-independent senior housing, then to assisted living, and finally to a nursing home or equivalent. This progression is of course highly country and culture dependent. (Nishita, 2006, p. 52.) In Finland the current main housing options aimed at older people can be categorized into independent housing (regular apartments and senior housing, possibly with visits by home care workers), assisted living (ordinary and intensive sheltered housing in assisted living facilities), and institutional care (nursing homes and long term health centre or hospital care (Helminen et al., 2017, p. 49; Jalava et al., 2017, p. 17). As noted in the previous section, of the above, in Finland everything up to and including intensive sheltered housing is considered living at home (STM, 2017a, p. 15). Of course, the concept of home is vastly different between for example a detached house and a group living arrangement in intensive sheltered housing. In addition, there are less established options such as family care and communal multigenerational blocks that do not directly fit this typical continuum and are at least as of yet somewhat marginal.

The definition of independent housing in regular apartments is rather self explanatory: one lives in their own dwelling that is not part of any assisted living facility. Though the dwelling itself is characterized by independence from any care facility, the independence of the resident can vary. They may for example receive more or less regular external home care or rely on informal care given by e.g. their partner or family members. At its core, senior housing is the same, though usually more guaranteed to be accessible and located near services—possibly including an assisted living facility—and typically aimed at people 55 years of age or older (ARA, 2015, p. 20; Post and Tyvimaa, 2010, pp. 38, 56). There is, however, no single clear let alone official definition, so actual implementations vary greatly from regular accessible apartments to practically sheltered housing (Post and Tyvimaa, 2010, p. 38).

From the perspective of care provision, the main difference between the two forms of assisted living discussed here, ordinary and intensive sheltered housing, is the time staff is present. In ordinary sheltered housing there is typically staff available only during the day, while intensive sheltered housing is staffed around the clock (Helminen et al., 2017, p. 49; Lehmuskoski, 2005, pp. 81–82). In both, residents require assistance in daily activities (Lehmuskoski, 2005, p. 147). Architecturally, ordinary sheltered housing typically takes the form of small apartments, each with their own kitchen and bathroom, that usually share more common areas than ones in regular housing, but are independent in the sense that using those common areas is not a day to day necessity. The apartments are also usually not entered directly from the non-corridor common spaces. In contrast, intensive sheltered housing in Finland is typically arranged as a group home. Here each resident (or more rarely two residents) has their own small apartment, usually with a bathroom but without a kitchen, but shares directly connected common areas such as a shared living room, kitchen, and dining room with other residents of the group home unit. (Helminen et al., 2017, p. 49; Lehmuskoski, 2005, p. 148.)

From an organizatory perspective, what differentiates (intensive) sheltered housing from institutional care is that in the former the residents always either rent or own their apartment (Helminen et al., 2017, p. 49). In terms of the daily living environment, however, the line between intensive sheltered housing and institutional care is not entirely clear, since the care needs of the residents and correspondingly the care provided are often very similar (Valvanne and Noro, 1999, p. 1592). Considering that the people who used to be in institutional care now tend to be in intensive sheltered housing (Official Statistics of Finland, 2019c; THL, 2020), this is only to be expected—the care needs are the same regardless of what the housing model is called.

In Finland, between the years 2000 and 2018 the total number of clients in the established forms of housing services for older people has risen 20.7%, from approximately 101 000 to 122 000 (see figure 3). During the same time, however, the share of older people this constitutes has fallen from 13.0% to 10.1%. Furthermore, as can be seen in figure 3 the absolute numerical increase is mostly due to more people receiving regular home care (up 31.4%), while the sum of other housing services has risen much less (9.6%). Thus more older people currently live at home in regular apartments, either independently, with informal care from e.g. relatives, or with the aid of formal home care, than did at the turn of the millennium, both proportionally and in absolute numbers. This development aligns with many other nations, e.g. a majority of the UNECE (United Nations Economic Commission for Europe) countries (Rodrigues et al., 2012, pp. 18, 86). The distribution between different kinds of care arrangements itself is similar to other Northern European countries. Conversely, in Southern European countries and the United States assisted living has a vastly smaller role, and informal home care is much more common (Barczyk and Kredler, 2019, p. 27.) In line with the above, in Finland, as in Northern Europe in general, it is very rare for older people to live with their adult children. Moreover, the separate residences tend to be further apart than in Southern Europe. (Isengard, 2013, pp. 248–250.) Thus opportunities for informal care by family are comparatively limited. Of those Finns who live in some sort of a care facility, the overwhelming majority are in intensive sheltered housing, while living in ordinary sheltered housing is much rarer. This points towards assisted living being a last resort option for when life in a regular apartment becomes impossible. Institutional nursing home care is rarer still, and long term health centre or hospital accommodation is nearly nonexistent.

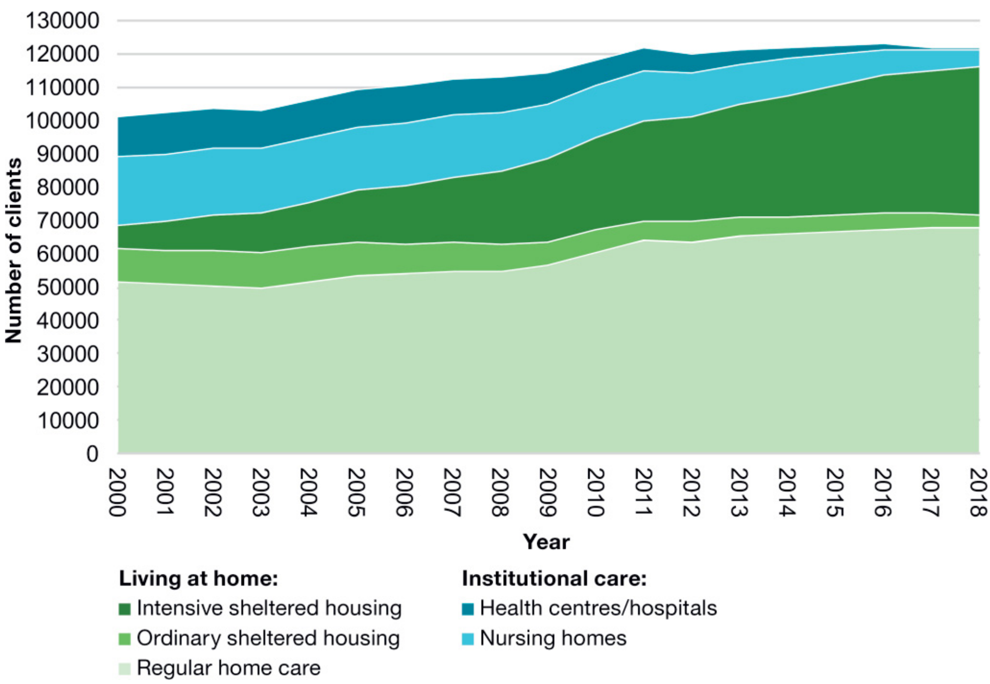


Figure 3. Number of clients aged 65 or older in different housing services in Finland. Housing services presented in green constitute 'ageing at home', while the rest fall under institutional care (STM, 2017a, p. 15). Data sources: Official Statistics of Finland (2019c) and THL (2020).

From the above, it is clear that nearly all of the older Finnish population (99.2%) lives in either regular apartments or intensive sheltered housing. Of these, the former is vastly more common: at the end of 2018, 95.5% of Finns aged 65 or older lived at home—89.9% without regular home care—and 3.7% were in intensive sheltered housing. The clienteles of all housing services are heavily weighted towards the oldest age groups, approximately half of all clients being at least 85 years of age. As can be expected, regular home care has the youngest clientele, while more institutional settings skew older. (Official Statistics of Finland, 2019c; THL, 2020.) As the share of the oldest old increases (Eurostat, 2020), the need for intensive sheltered housing in particular is expected to rise (Andersson, 2007)—likewise for similar housing models across Europe (e.g. HAPPI, 2009; Spasova et al., 2018). So far this does not seem to have been the case in Finland, though: despite the number of people aged 85 or older increasing 88.3% between the years 2000 and 2018, the share of those who are in either assisted living or institutional care has in fact fallen from 6.4% to 4.5% (Official Statistics of Finland, 2019c; THL, 2020). Regardless, it is unlikely that the need for intensive sheltered housing will disappear entirely, at least in the near future, no matter the advances in home care and individual ability to function. Thus, despite shifting percentages it seems that regular apartments and intensive sheltered housing (i.e. group homes) will continue as the dominant dwelling types for older people and thus need to be considered in future housing provision.

1.2. Correspondence between the housing stock and housing needs

As was established in section 1, in Finland like many other countries the phenomena of population and building stock ageing are largely concentrated in the same areas, predominantly in post-war mass housing estates. Furthermore, these areas and estates tend to be located in places that are simultaneously undergoing the greatest decline in total population (Eurostat, 2019; Riihimäki et al., 2019, p. 10). For Finland this trend can be clearly seen in figure 4, where change in total population is plotted against change in the proportion of people at least 65 years of age on a per municipality basis. As a consequence, many areas are faced with a growing mismatch between the properties of existing housing and the needs of the ageing population, with ever fewer resources to address the issue (e.g. Demirkan, 2007, p. 33; Pettersson et al., 2017, p. 9).

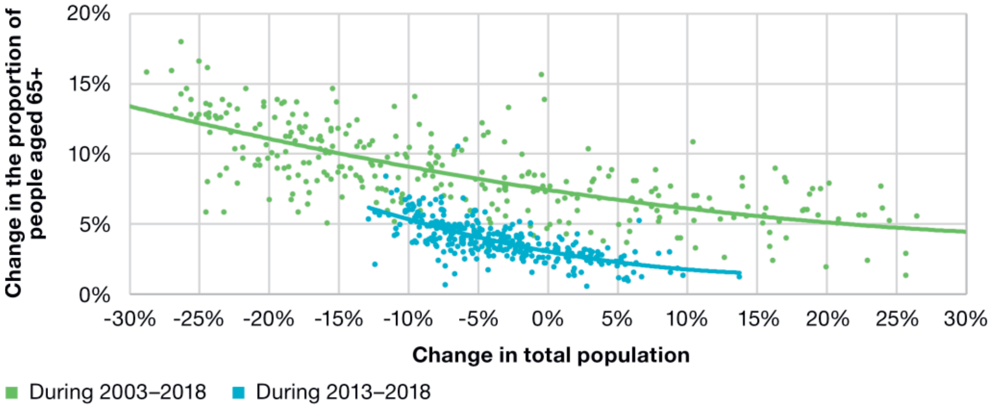


Figure 4. Total population change and change in the proportion of older people in Finland. Each dot represents a Finnish municipality. Data source: Official Statistics of Finland (2019a).

Furthermore, based on a GIS-analysis of Finnish suburban housing estates, Stjernberg (2019, p. 245) considers it likely that the ageing population structure of these ageing estates is largely composed of people who have aged with the buildings, having lived in the same location for a long time, perhaps even since the buildings were constructed. This view is shared by Helminen et al. (2017, p. 45). Similarly, Fernández-Carro and Evandrou (2014, p. 48) have noted that although there are differences between countries, residing in one place is a widely observable phenomenon among older Europeans. In addition, approximately 80% of Finnish people aged 65 or older own their dwelling (Jalava et al., 2017, p. 17), which has been singled out as the most determining factor for ageing in place across continental Europe (Fernández-Carro and Evandrou, 2014, p. 48). Taking into account the effects of place attachment (section 1.1.1) it is clear from a social quality of life perspective that the issue of a housing stock that is inadequate for older people cannot be fixed solely through new construction and relocation, even where it would be feasible. Instead, this inadequateness, which has been pointed out as one of the biggest reasons for older people moving into assisted living (Verma and Huttunen, 2015), should primarily be addressed by adapting the existing buildings.

1.3. Building adaptation as a response to changing housing needs

Owing largely to the combination of widely ongoing building stock ageing and changing housing needs (sections 1–1.1), existing buildings are increasingly seen as valuable spatial reserves, and building adaptations as an alternative to new construction (Kohler and Hassler, 2002; Kovacic et al., 2015; Rockow et al., 2019). These adaptations can cover a wide range of renovation measures from simple refurbishment such as changing fixtures or removing thresholds to major repurposing such as converting regular apartments to assisted living. The motivations behind the increased interest in better utilization of existing buildings are of course also varied, comprising aspects related to e.g. technical building performance, financial gain, utilization efficiency, and user or resident wellbeing. What is common regardless of the underlying reasons, however, is the goal of extending building life spans by avoiding obsolescence. (Heidrich et al., 2017; Rockow et al., 2019.)

Corresponding to the above, renovation has been identified as the main challenge—and simultaneously opportunity—for successfully providing housing for older people, especially in areas where both the population and building stock are ageing (Hynynen, 2018; Jalava et al., 2017; Lansley et al., 2005, p. 950; Nishita, 2006, p. 52; Pettersson et al., 2017, p. 8; Slaug et al., 2020; Verma, 2019, p. 171; Verma and Taegen, 2019; Ympäristöministeriö, 2012). Even ignoring the quality of life implications of forced relocations, in many such areas new construction to address housing needs may be economically infeasible. On the other hand, adapting the existing buildings has been argued to be potentially both more agile to changing needs and less expensive to implement than new construction (Nishita, 2006, p. 52). Furthermore, there is the perspective of ecological sustainability to consider. In many areas of Finland at least, the number of apartments already exceeds the number needed, and the issue is merely them being unsuitable for the ageing residents due to being inaccessible or otherwise in need of repair (Hynynen, 2018). In such a situation new construction without considering alternatives is highly questionable. Instead, efforts should be made to extend the life span of existing buildings to minimize the need for demolition and replacement (Thomsen and Van Der Flier, 2009, p. 658).

Potential impact of building adaptation

Supporting renovation as a strategy for housing the ageing population, it is overall well acknowledged that home adaptations addressing the needs of older people can have a significant positive impact on independence and wellbeing as well as at least delaying the move to an assisted living facility or other forms of more institutional care (e.g. Fänge and Iwarsson, 2005; Fox, 1995; Heywood, 2001; Hwang et al., 2011; Lansley et al., 2005, p. 950; Niva and Skär, 2006; Petersson et al., 2009; Pettersson et al., 2017; Slaug et al., 2020, p. 13; Tanner et al., 2008, pp. 207–208). What specific changes these adaptations ultimately include is of course highly case dependent, due to varying personal needs and properties of the existing built environment. Regardless of the scope of changes required, however, in the field of gerontology it has long been considered that a good fit between the abilities of a person and the requirements posed by their environment promote psychological wellbeing and general quality of life by maximizing an individual's (independent) performance (Lawton and Nahemow, 1973; Niva and Skär, 2006, p. 22). Correspondingly, in order for the environment to not limit this ability to function, the whole built environment must provide at least a certain base level of accessibility (e.g. Verma, 2020). Furthermore, as already briefly noted in relation to increasing home care in section 1.1, in addition to affecting one's independent ability to function the accessibility of living environments is also important for the work of caregivers (Pettersson et al., 2020, p. 12; Tanner et al., 2008, p. 208). This includes ordinary housing as well as the surroundings, where accessibility enables the maximum amount of time to be spent on the actual care instead of e.g. moving the resident (Ahrentzen and Tural, 2015, p. 596).

Considering the major impacts of maintaining one's familiar environment (section 1.1.1), it is evident that at least in some ways the adaptation of existing apartments can not only match but even surpass new construction in terms of quality of life. For an ever increasing number of older people, however, even regular home care is not enough (section 1.1.2, figure 3), leading to an increasing need of assisted living. Therefore, for all the same reasons that apply to independent housing, assessing the possibilities of the existing building stock should take into account not only refurbishment but also repurposing to support the housing needs of those no longer able to live independently.

Assessing building adaptability

Seeking to increase the knowledge base on options available for building adaptation, and to facilitate actual adaptations, a sizable body of research has accumulated on the topic of assessing building adaptability. For example, taking the broad perspective of both research and practice on building adaptability, Heidrich et al. (2017) have conducted a systematic literature review covering the years 1990–2017 to identify gaps between defined needs and the existing state-of-the-art. The identified gaps include e.g. determining the characteristics influencing the adaptability potential of a building and developing precise but convenient ways of assessing adaptability. Furthermore, having restricted their scope to adaptability in new construction, the authors highlight the need to include renovation measures in future work on the topic. In their state-of-the-art review of modeling and quantifying building adaptability, Rockow et al. (2019) present nine tools or models grouped into three categories: ones to aid the initial design of new buildings, ones to assist owners in determining if adaptations should be made, and ones to examine the path of a building from obsolescence through adaptation to relevance. Based on the review the authors conclude work on the topic to still be 'in a nascent stage' (p. 13), needing improvements especially in the development of models based on large quantitative data sets instead of case studies of limited scope.

As an example of a specific recent approach, Herthogs et al. (2019, p. 1) have developed a quantitative assessment method for building layouts utilizing weighted graphs, where they divide a building's capacity to support changes into two components: 'generality (passive support for change) and adaptability (active support for change)'. The goal of the method they have named SAGA (Spatial Assessment of Generality and Adaptability) is to quantify 'how well a building's spatial connectivity network can support change' (ibid., p. 2). At its core, the method is based on justified plan graphs, which in turn are a part of a wider collection of analysis methods included in the Space Syntax theory (UCL Space Syntax, 2020). The authors assert that the generality of a plan is mainly determined by the permeability of its connectivity graph, i.e. the number of links between distinct spaces. Relatedly, they state that adaptability can be evaluated based on the extent to which it is possible to create new connections between spaces. In its presented form, the methodology is solely focused on connectivity, but the authors note that initial work has been done on complementary 'modular' extensions that could include aspects such as space floor areas and options for changing space boundaries.

Building adaptation for older people

While presenting a range of motivations for addressing building adaptability, all of the work discussed above is neutral in their approach. They aim to provide an objective assessment without being tied to any specific target functionality—although the modular methodology envisioned by Herthogs et al. (2019) seems to be a step towards combining these aspects. When it comes to the current topic of housing the ageing population, existing methodology for assessing adaptability to the corresponding needs appears practically nonexistent. This is not to say the topic of housing adaptation for older people has not been explored—there is a great amount of research. However, it tends to be focused on one or more of the following: the reasons for needing adaptations, the types of adaptations usually conducted, and the kinds of the effects those adaptations have had.

For example, examining data on 397 dwellings in southern Sweden, Pettersson et al. (2017) studied the accessibility issues most commonly addressed in renovations and the effects eliminating those issues had. They concluded that the most common adaptations—e.g. removing thresholds, adding grab bars, replacing bathtubs with showers—often had a considerable effect on the residents' ability to function independently despite being relatively minor alterations. Studying a sample of Swedish housing adaptation grant recipients, Fänge and Iwarsson (2005) started by recording common accessibility issues in the recipients' homes. This was followed by studying the impact the adaptations had on the accessibility of those homes and the residents' ability to function. Again, most adaptations comprised installing grab bars or removing bathtubs, although instances of entirely new bathrooms or kitchens being constructed were also noted. Despite the fact that during the course of the longitudinal study the residents' functional limitations and dependence on mobility aids increased, their overall ability to use their apartment still improved due to the adaptations. Based on the results, the authors emphasized the need to tailor adaptations to each resident's personal needs. This sentiment is echoed by the results obtained by Heywood (2001). In their study similar small adaptations proved highly effective, while most complaints were focused on personally unsuitable appliances and poor workmanship. In a longitudinal questionnaire study of five participants, Niva and Skär (2006) reported similar results after adaptations being conducted mainly in the kitchen and the bathroom: after the adaptations all participants were more active and more able to perform daily activities independently. They also required less rest periods during the day. In the same vein, Thordardottir et al. (2019) used semi-structured interviews to assess the impact housing adaptations had on older people's participation in everyday life over a twelve month period. In this case too, the adaptations comprised small singular changes as listed above. The authors obtained positive to neutral results, with some participants experiencing positive change and others showing no notable improvement in their ability to function.

In Finland, Sorri (2006) has assessed the suitability of apartment buildings from the 1950s to 1980s for housing older people, noting numerous issues with accessibility ranging from floor level differences to the materials used. Likewise in Finland, Kajanus-Kujala (2008) has assessed the impact housing adaptations have had on older people's ability to continue living at home in regular apartments. Similarly to most other studies, the results suggested that the adaptations had had significant benefits in enabling the residents to remain independent. The question was also raised whether some of the adaptations had been started too late, since some of the participants had deceased either during the renovation process or during the follow-up period. Correspondingly, the author stated that adaptations conducted early are very likely to have more of an effect than those done at the very last moment.

Spatial perspectives in building adaptation for older people

Although the above is by no means an exhaustive representation of the ample body of research on housing adaptations, it is illustrative of the adaptations usually covered as well as the effects observed. In contrast, and notably from the perspective of the current work, there is much less literature on housing adaptations specifically targeting changes to spatial arrangements or the use of spaces. Kovacic, Summer, and Achammer (2015) conducted a theoretical case study of the renovation potential of an early 20th century Austrian housing block, in which some of the examined strategies included converting apartments to assisted living for older people. Due to their specific perspective the authors did not, however, describe any of the actual spatial changes required aside from listing '[m]odification of the business office to a recreation room/nursing care base' and 'installation of bathroom and universal accessibility' (p. 7). Instead, they mainly focused on life-cycle cost calculations. On these grounds, the refurbishment was found financially highly beneficial in the long term compared to building new nursing homes, and the social and financial value of the existing building stock was noted. However, nothing can be concluded about the feasibility or successfulness of the repurposing from an architectural perspective.

In a report by the Finnish Ministry of the Environment, Lyytikkä and Kukkonen (2006) examined ten completed repurposing cases in apartment buildings from the late 1960s to the early 1980s. Four of these were conversions into assisted living group homes for older people. The goal of the authors was to report on renovations that would be exemplary, i.e. broadly applicable also in other cases, taking into consideration functional, technical, and financial matters. The spatial analysis conducted was on a very general level, as it was noted that increased detail would require a larger sample of projects. Among their main spatial observations the authors noted that most assisted living apartments in the studied repurposing projects were too small by current standards and lacked private bathrooms. This was highlighted as a particularly common, significant challenge. Despite these issues, the repurposing projects had been considered largely successful and overall beneficial for the neighborhood, among other things increasing the general desirability and peacefulness of the area.

A thematically similar, though much more limited in scope, study was conducted by Kakko (2011). In their master's thesis in architecture they examined the potential for providing assisted living for older people as part of an overall refurbishment of a Finnish post-war apartment block. An example design was provided as a result, showing one possible solution. However, no actual analysis of feasibility was presented, and the successfulness of the design was not assessed.

Common accessibility issues in the building stock covered by this dissertation have also been examined in a master's thesis in architecture by the current author (Kaasalainen, 2015). The work combined literature review with archival research for an evaluation of typical apartment layouts, culminating in generalizable renovation plans for the most common designs (pp. 174–251). These parts of the thesis laid the foundation for the current research, with further development of the work forming the included articles II and III. In addition, the thesis observed the common interior and exterior areas of the buildings on a more general level to discuss their suitability for older people. The potential for repurposing was identified, but not included in the scope of the work.

Further case studies similar to those described above for Finland may of course exist locally elsewhere too. However, if they do, none were found in English at the time of writing this dissertation. Overall, as noted earlier it appears there is little scientific—or more practice oriented for that matter—work prioritizing a spatial perspective. Furthermore, what little there is mostly focuses on very restricted numbers of cases. This greatly limits the potential for generalizable observations, especially without complementary information on wider sections of the corresponding building stock(s) for comparison.

1.4. Research objectives and scope

As established in the preceding sections, the need for adapting the existing apartment building stock to support ageing at home is widely acknowledged, as is the general potential in those adaptations for supporting independence and wellbeing. What is largely lacking, however, is research on how those adaptations could and should be conducted (e.g. Pettersson et al., 2017, p. 9; Smith et al., 2008, p. 302). More specifically, information on the changes to existing spaces that are on the one hand needed, and on the other possible, is extremely sparse. This dissertation addresses the knowledge gap by focusing on the spatial renovation possibilities of the existing apartment building stock, aiming to assess how well it suits or could suit the most common forms of housing for older people.

In this dissertation two types of housing for older people are studied: independent apartments with or without home care and assisted living group homes. These currently cover the vast majority of housing arrangements for Finnish older people at 99.2%, and the situation is unlikely to change significantly any time soon (section 1.1.2). Furthermore, due to the significant differences in spatial requirements between the two, most notably the inclusion of shared and staff spaces in group homes, this greatly increases the future potential for utilizing the results obtained and the methods developed. Since the studied buildings obviously already contain independent apartments, examination from the perspective of independent housing for older people includes assessing both the original state and the potential for adaptability. Repurposing into assisted living, however, by definition focuses on adaptability. Corresponding to the above, in this dissertation the spatial potential for ageing at home in the Finnish apartment building stock is addressed through the following two main research questions:

1. How suitable or adaptable are existing apartments for independent housing for older people?
2. How adaptable are existing apartment building floors into assisted living group homes?

The immediate context of the research is Finland. However, building stocks with similar issues and spatial characteristics exist in many other countries, making it highly likely that the methodology employed and even the potentials observed have significantly wider applicability (sections 1 and 4.4). More specifically, the research focuses on Finnish multi-storey apartment buildings from the 1970s. As discussed earlier, similarly to many other countries these buildings form a significant part of the current Finnish apartment stock (Official Statistics of Finland, 2019a; Stjernberg, 2019, p. 18), constituting nearly a quarter (23.7%) of all dwellings in apartment blocks and a ninth (10.9%) of all dwellings in any building type (Official Statistics of Finland, 2019b). Also similarly to other countries, the buildings are currently in urgent need of renovation for many reasons (Dhima, 2014, p. 7; Hietala et al., 2015, p. 21; Lehtinen et al., 2005; Riihimäki et al., 2019, p. 17; Stjernberg, 2019) and thus a propitious target for including accessibility improvements among the technical refurbishment that is required in any case (Hynynen, 2018; Jalava et al., 2017; Verma and Taegen, 2019; Ympäristöministeriö, 2011).

In Finland this part of the building stock already houses a large share of the ageing population (Lankinen, 1998; Stjernberg, 2019), and is typically located very suitably for housing older people in or near local urban centres (Riihimäki et al., 2019, p. 20). Improving suburban housing estates has also been highlighted as a key focus for the development of cities in the current Finnish government program (Finnish Government, 2019, p. 53). Furthermore, a large part of the stock is public rental housing (Kakko, 2011, pp. 120–121; Laine, 1993), in which vacancies are disproportionately common especially in declining municipalities (Riihimäki et al., 2019, pp. 11, 18; Ympäristöministeriö, 2017, pp. 19–21). This increases not only the need for but also the feasibility of even large scale renovation or repurposing endeavors. Finally, this part of the building stock is considered to be highly repetitive both spatially and structurally (Hytönen and Seppänen, 2009; Mäkiö et al., 1994; Verma, 2019). Knowledge of this, although prior to the current research based on limited samples, expert opinions, or 'common knowledge', further supports its selection as the object of study for this dissertation.

In this dissertation, the concept of 'spatial' properties refers to the directly measurable, plan level physical dimensions of spaces, such as their area and width, and the connections between those spaces. Correspondingly, properties such as surface materials, patterns, colors, and lighting are not examined in depth. While these are essential for high quality housing in general, and especially for residents suffering from physical or cognitive decline, they can often be adjusted quite independently from the aforementioned spatial properties. These perspectives have also been discussed in detail in previous Finnish language work by the current author, in relation to the same Finnish apartment building stock (Kaasalainen, 2015) as well as in relation to the design of assisted living group homes (Kaasalainen et al., 2018). Structural properties, e.g. the locations of load bearing walls, are examined in this work to the extent that they affect current spatial configurations and the modification possibilities thereof. Other technical issues such as HVAC and electrical installations are acknowledged as an important part of comprehensive refurbishment and as something that can affect the labor intensiveness and costs of renovation. Likewise, they are important factors of housing quality, especially for older people who might e.g. be less able to cope with unsuitable temperatures (Hughes et al., 2019). However, for the reasons noted above for materials etc., these are also mainly excluded from the current scope. An exception to this is the bathroom, for which the difficulty of rearranging and resizing wet spaces is considered. Furthermore, various gerontechnological systems that could range from sensor based lighting to robots and exoskeletons (Pereira, 2018) are not considered, on the grounds that they are at least not yet an alternative to accessible design, while the renovation need is very much present. Finally, observations and analysis are conducted within the studied buildings. Therefore, exterior spaces such as yards, although also acknowledged as having a significant effect on any single concrete case and noted as a further research topic, are not part of the current examination focusing on the properties of the whole studied stock.

1.5. Research structure and process

As described in the previous section, the main types of housing for older people addressed in this dissertation are (**1**) **independent apartments** and (**2**) **assisted living group homes** (for definitions see section 1.1.2 or glossary). From a spatial perspective, studying the suitability and adaptability of existing buildings to these uses demands (**A**) **characterizing the spaces and their properties available** in existing buildings, (**B**) **characterizing the spaces and**

their properties required for the proposed uses, and (**C**) **comparing the fit between the available and required spaces.** Additionally, (**D**) **determining the relevant structural properties** of the adaptation target buildings is necessary to ensure practical feasibility of the proposed spatial arrangements. Consequently, the research structure of this dissertation can be expressed as a matrix of housing types (**1–2**) and actions related to the evaluation of spatial properties (**A–D**). This structure, along with the corresponding articles included in the dissertation, is shown in table 1.

Table 1. Research structure of the dissertation in terms of the articles included. The structure is formed as the product of studied housing types and evaluation of spatial properties.

	1. Independent apartments	**2. Assisted living group homes**
A. Characterizing spaces available	Article II	Articles I and III
B. Characterizing spaces required	Article III	Article I
C. Comparing spaces available and required	Article III	Article I
D. Determining relevant structural properties	Primarily article IV[a], supplemented by articles I and II	

[a] The main focus of article IV is the reuse of construction elements from existing buildings. While that information is not directly relevant to the topic of this dissertation, the article and related research also include a comprehensive survey of structural properties using the same sample as articles I–III. Thus, as referred to further on in the dissertation, the article forms an important part of the research by providing information on the structural properties of the studied buildings.

In accordance with the above structure, after presenting the theoretical background, methodology, and materials (section 2), the dissertation first provides a characterization of existing apartment buildings (3.1) and an assessment of their suitability for independent housing for older people (3.2). This is followed by a characterization of existing group homes to define the spatial needs of repurposing apartment building floors (3.3), continuing into an assessment of the feasibility of this repurposing (3.4). Finally, the theoretical and practical implications of the research are discussed (4.1 and 4.2), as are the reliability, validity, and limitations of the research (4.3), followed by the conclusions (5) summarizing the findings and suggesting avenues for further research.

The research constituting this dissertation was conducted at Tampere University (TAU; prior to the year 2019 Tampere University of Technology, TUT) School of Architecture, partially connected to research projects. Chronologically, the research for article IV was conducted first, in the research project ReUSE (Repetitive Utilization of Structural Elements) implemented during the years 2013–2014 by the TUT School of Architecture and Department of Civil Engineering with VTT Technical Research Centre of Finland. TUT's part of the project was financially supported by the Finnish Ministry of the Environment and Ekokem Corporation. Articles II and III followed, in this order, in the research project MuutosMallit (Lähiökerrostalojen ja -asuntojen Muutossuunnittelun Mallit) [Modification Models for Mass Housing Blocks and Flats]. This project spanned the years 2013–2015 and was funded by the Housing Finance and Development Centre of Finland (ARA) as part of their development programme for residential areas. For article I there was no direct project connection. However, the material on assisted living group homes was collected in the research project COMBI (Comprehensive Development of Nearly Zero-Energy Municipal Service Buildings). The project was implemented during the years 2015–2018, led by TUT's Department of Civil Engineering with participants including research groups from TUT, Aalto University, and Tampere University of Applied Sciences. The project was supported financially by the European Regional Development Fund, The Finnish Funding Agency for Innovation (Tekes), and 37 private companies. In addition, the finalizing phases of the research were supported by the Finnish Foundation for Technology Promotion (Tekniikan Edistämissäätiö) through a personal encouragement grant.

2. METHODOLOGY AND MATERIALS

The main research approach of this dissertation is compiling and utilizing quantitative data on the studied building stock in a way that also enables generalizable qualitative observations made through a manageable set of representative cases. Based on this aim, the methodological foundation is formed by combining building stock research and typological classification. Thus, this section first briefly introduces those concepts (2.1). Following this, building adaptation research as an application of building stock research and typological classification as employed in this study is discussed (2.2). Finally, the current research materials and their use are described (2.3).

2.1. Building stock research and typological classification

According to Kohler and Hassler (2002), gathering information about building stocks in Europe originated in housing surveys conducted from the end of the nineteenth century onwards. In these surveys the primary emphasis was on creating cost estimates for future construction. It took until the late 1980s for major interest in renovation to arise, then mainly driven by questions of energy consumption and based on production statistics. On the whole, the authors characterize early research approaches into building stocks as being 'typically concentrated on specific parts of the stock, with limited objectives and little attempt to generalize these findings' (p. 227). Since then, research approaches have shifted towards studying the whole building stock, utilizing a greater variety of methods, and striving for increased generalizability and the ability to combine results from multiple studies (ibid.). Corresponding to this change, Kohler, Steadman, and Hassler (2009, p. 450) assert that building stock research as it is now understood started in the early to mid-1990s, and has since gained ground especially after the turn of the millennium.

Compared to the modern approach focusing on large data sets and generalizability, the traditional form of building stock research described by Kohler and Hassler (2002, p. 227) can be considered to be more akin to single case or small sample collective case studies (Goddard, 2010). Assuming finite resources, such a highly focused approach has clear benefits when it comes to the feasible depth of exploration of a specific example on virtually any given topic (Xiao, 2010). On the other hand, the potential disbenefits are equally clear. If it is not known which properties of the current object of study are shared by others, or how many others, the generalizability of the results obtained can be limited—at least horizontally, i.e. to other samples of the same population (Frey, 2018). While generalizability is not a prerequisite for meaningful research, its importance in the context of assessing building stocks is rather obvious.

Considering the complexity and vastness of an entire building stock, or even a sizable part of one, simply combining the depth usually associated with a single case study (Elger, 2010) with the breadth of modern building stock research is likely to be very rarely feasible. Seeking to address the above problem, many researchers have employed a typological approach to building stock research. Here typology is understood as 'the study of types, or a system of dividing things into types' (Cambridge University, 2020). Within this definition, a type describes, and is defined by, a set of characteristics common to all individual instances within the type. The instances described by a type or types can be either existing cases or theoretical ones. (Moneo, 1978, pp. 23–24; Van Leusen, 1994, p. 21.) Thus the typological approach to building stock research consists of determining the recurring properties of the stock, possibly with the futher goal of analyzing large volumes of information through a more manageable set of individual cases, which represent specific types. Although not a defining part of building stock research, such systematical categorization endeavors are a logical extension.

Corresponding to the above distinction between existing and theoretical cases, there are different ways of forming a typology. Looking at earlier approaches to forming an architectural (housing) typology, Van Leusen (1994, pp. 46–71) distinguishes between precedent-based and representation-based typologies. They assert that in precedent-based typologies 'a type's essential characteristics are not systematically described but are largely to be interpreted from the paradigmatic precedents supporting it' (p. 46)—the distinction between different types can be mainly implicit. In contrast, in representation-based typologies type descriptions are specified 'independently from any particular instances of [the] types' (p. 53)—for some types actual instances might not exist at all. Of course even in this approach the author is likely to have some knowledge of reasonable spatial arrangements, probably formed by observing precedents. This in turn may lead them to setting certain restrictions for the typology, such as requiring all spaces of an apartment to be connected by an interior route.

While a type allows variation, it is also fundamentally a fusion of similar singular instances with certain shared characteristics (Argan, 1963; Van Leusen, 1994, p. 21). Correspondingly, regardless of whether the creation of a typology is based on precedents, informed by precedents, or entirely independent of precedents, a key consideration in all typological approaches is what characteristics are included in the type descriptions and definitions in order to form meaningful distinctions with useful granularity (Famuyibo et al., 2012). The planned use of the typology thus formed, if any exists, must also be taken into account when determining these criteria. For example, discussing precedent-based typologies van Leusen presents a work titled 'Modern housing prototypes' (Sherwood, 1978, cited in van Leusen, 1994, pp. 51–53), in which the most detailed level of typology concerns individual apartments. These apartments are primarily categorized based on their number of façades with windows, and further divided into subtypes based on the location of the kitchen, the bathroom, and if present the stairs. Due to the type defining characteristics chosen, such a typology illustrates the overall arrangements found in the included sample quite efficiently, and might be highly useful for e.g. considering the relationship between the interior living spaces and the exterior. On the other hand, with no distinction between apartments with different room counts, very little can be said about e.g. the apartments' suitability for families of different size.

As noted earlier, according to van Leusen (1994, p. 46) precedent-based typologies categorically tend to lack a systematic description of the criteria distinguishing the types. However, this is not a limitation inherent in using precedents to form a typology. While a sample of precedents likely will not cover all existing (let alone theoretically possible) cases, meaning that the typology based on it is incomplete, the defining criteria behind the typology may still accommodate the addition of such cases. Thus a systematically defined precedent-based typology can be extendable to be independent from its initial particular instances of types. To maximize future uses of a typology, some of which might still be unknown when it is first created, this should be striven for whenever possible. Furthermore, such a clear definition facilitates combining results from multiple studies, as highlighted by Kohler and Hassler (2002, p. 227). Even if separate typologies are not directly compatible, a sufficient description of defining characteristics allows the later creation of connections.

Similarly to the variety of ways for defining a typology, within the shared general typological approach a wide range of methods and foci are found in existing work utilizing said approach. This is true even when restricted to the topic of building stocks and the specific goal of forming a typology based on a certain sample to be used for a certain purpose, rather than seeking to create a more general categorization system. For example, focusing on technical performance, Famuyibo, Duffy and Strachan (2012) used statistical analysis to form archetypes of Irish residential buildings for assessing the impact of various energy retrofits. In contrast, Ju, Lee and Jeon (2014) sought to identify local design characteristics in Malaysia from the perspective of essential housing needs, to which end they analyzed the site, building, and apartment plans of projects from 34 precincts of Kuala Lumpur. Taking a yet different kind of an approach to forming a typology of spatial properties, Degenholtz et al. (2006) used cluster analysis of features in a sample of nursing homes to define types for resident rooms and care facilities. While the above are clearly just a brief highlight of the existing body of work, the great variety present already illustrates use of the approach to a myriad of purposes.

2.2. Research approach and methodology

In Finland, like many other countries, the concurrent phenomena of population and building stock ageing create a multifaceted renovation need in the most numerous part of the apartment stock. Spatial unsuitability in the form of e.g. accessibility issues is a major component of this renovation need, necessitating spatial adaptations. (Sections 1–1.2.) Correspondingly, an approach into building adaptation that considers the shared properties of the most affected part of the building stock is useful—and arguably even required—to address the issue effectively. At the same time, the vastness of the stock makes such an approach highly challenging. This is evidenced by existing work in Finland and elsewhere mainly observing housing adaptations either conceptually, through quite limited sets of cases, or both (section 1.3). Clearly the methods available for a single case study cannot feasibly be used to examine each existing building or apartment individually. Aiming to combine in-depth observations and analysis with wider generalizability, the current research utilizes typological classification as an approach to building stock research, to assess the spatial suitability and adaptability of Finnish post-war mass housing to the needs of older people.

As the title indicates, the goal of this research is to assess the potential for ageing at home in the Finnish apartment building stock. However, despite primarily being a means to an end, the methods developed for this assessment are also a key part of the research contribution of the dissertation. While typological approaches to building stock research have often been employed (section 2.1), and methods for adaptability assessment have been developed (section 1.3), no overarching method fit for the current purpose could be found in existing work. Thus the methodological development in the dissertation not only builds a basis for the current work and any extensions, but when presented together with the findings also exemplifies the potential of a typological approach for producing knowledge that is widely and relatively easily applicable in practice. Therefore the methodology is discussed in more detail alongside the resulting findings in section 3. The goal of this is to more clearly show how the results presented were reached and how the methods employed could be further utilized. Correspondingly, the following subsection aims to present a more general overview of the approach and principles on which these methods are based on.

2.2.1. Adaptability assessment through typological building stock research

In principle, the concept of types is involved from the very beginning in defining the scope of the current research. Firstly, focusing on multi-storey apartment buildings (thus excluding e.g. detached houses and row houses) already constitutes a typological choice. Secondly, restricting the examination to a specific vintage, i.e. the 1970s, can be considered another one. (E.g. Moneo, 1978; Van Leusen, 1994.) However, at least when ignoring rare hybrid buildings or multi-stage construction processes, the above categorizations are quite straightforward. What is not, is refining the categorization of spatial configurations further in a way that simultaneously includes sufficient generalizability and specificity for considering adaptability for certain purposes. Furthermore, the appropriate categorization can vary based on the goals of the adaptation. For example, for single apartment adaptations it is useful to know typical apartment layouts and dimensions of the spaces contained. On the other hand, a comprehensive building or building floor level repurposing might ignore existing apartment boundaries entirely, only requiring information on the total reserve of spaces available. In such a case even the existing room layout might not matter, only the structural building frame.

In theory it would be possible to construct a single general typological framework of spatial properties including all of the above aspects and more (see e.g. Van Leusen, 1994). However, for the current purpose of assessing a specific (part of) a building stock from a specific perspective, doing so is not required, though as briefly discussed in section 2.1 the potential is acknowledged for further extensions of the work. Given the available resources, the approach of many detailed case studies, would mean a reduction of depth in the examination of ageing at home potential, as also discussed in section 2.1. Secondly, the practical application of the results and methods is an important part of the current research and the increased complexity would most likely make this more difficult, negatively affecting the potential impact of the work when it comes to housing for older people. Therefore, a more purpose specific approach was chosen to best suit the goals and data of this research. As a result, the spatial characterization process of existing apartment buildings occurs in two distinct ways. These comprise a hierarchical typology of apartment layouts, where current physical spatial boundaries are primarily fixed, complemented by an assessment of potential spaces available overall, as defined by the structural building frame (see section 2.2.2 for details). Although these characterizations are obviously connected due to the shared sample, they are not fully interlinked in the sense that each space examined could be traced to both a certain apartment and a certain location in a single building. Corresponding to the goals of the current work, all of the typological characterization processes are precedent-based: types are determined based on certain existing cases, rather than aiming to include the full theoretical range of configurations possible (Van Leusen, 1994, pp. 24, 46).

Characterization of existing buildings

The characterization of existing apartment buildings (section 3.1) conducted in this research is founded on the principles of network theory. Network theory uses graphs, consisting of nodes connected by links, to represent and potentially examine the relationships between distinct objects (Newman, 2010). The term is often used synonymously with 'graph theory', but has been noted to be a subset of the latter, used when mainly focusing on the properties represented by a graph, rather than just the graph itself as a mathematical construct (Barabási and Pósfai, 2016). In the context of buildings, a network can be defined (for example) in terms of distinct rooms and their connections. At a basic level this kind of spatial mapping corresponds to conventional plan graph theory, where an access graph of spaces is constructed based simply on the existence of the spaces and the connections between them, with no further information on e.g. the dimensions of the spaces or the type of connection (Ostwald, 2011, pp. 450–451). The core approach is very versatile and expandable, and has been used by many researchers for a variety of purposes, e.g. by Brown and Steadman (1991) to study access patterns in British houses, by van Leusen (1994) as part of developing a general typology of complex residential buildings, and by Herthogs et al. (2019) as the basis for their building adaptability assessment method (see section 1.3). In this dissertation the basic access graph was complemented by recording the physical locations of the rooms in relation to each other, in addition to which the rooms were further distinguished as either kitchens, other habitable rooms, bathrooms, or halls. In accordance with the aim of utilizing quantitative data to enable generalizable qualitative observations, a set of representative theoretical type apartments was then statistically formed based on a much larger sample of actual cases. This has been previously noted to be one of the main opportunities for (justified) plan graphs when applied consistently to a sufficiently large set of cases (Ostwald, 2011, p. 465). Compared to just selecting certain existing cases, forming theoretical archetypes allowed closer correspondence to a higher proportion of actual apartments. The second characterization approach, an assessment of potential spaces available overall, stripped the examined buildings of all non-structural components, focusing only on the spatial boundaries set by the structural building frame. Due to the prevailing structural systems of the time, i.e. the crosswall frame, these boundaries amount to series of (practically always) rectangular spaces along the facades (see section 3.1.2), some spanning across the building. Thus, such spaces on a single floor could be quantitatively inventoried by simply recording their dimensions and noting which ones formed a pair, i.e. were opposite each other without a structural wall in between. For details on the above process, see section 3.1.1.

The characterization of existing assisted living group home units (section 3.3) was conducted in a network theory based manner similar to that used for the apartment buildings. Layouts were initially mapped as simple plan graphs with nodes representing each distinct function. Based on the variety of recurring functions observed, individual functions were then further grouped into space types based on shared connections to the chosen 'root ' space (Ostwald, 2011, p. 451), in this case the main corridor of a unit. Since no recurring pattern was discernible regarding the locations of the various functions, the final spatial representations essentially ended up as justified plan graphs with certain additional properties such as floor area recorded for each node. For details on the above process, see section 3.3.1.

Adaptability assessment

The assessment of suitability and adaptability of individual apartments to housing for older people (section 3.2) was based on research by design culminating in a multi-case study. Here research by design is understood as a method in which architectural design is a key part of both the research and its outcomes (Hauberg, 2011; Verbeke, 2013), and aligned with a systematic research inquiry it facilitates the creation of new insights and knowledge (Hauberg, 2011; Sevaldson, 2010). Thus, drafting architectural designs was used to investigate spatial use and adaptation potentials. This allowed much greater detail than would have been possible by only numerically comparing e.g. the connections between rooms and the dimensions of those rooms—or lists of other singular features, as was often the case in existing work on the topic (section 1.3). First, recurring accessibility issues in the existing apartments were determined by examining the main research sample in light of a literature review covering research, design guidance, and regulations. This was followed by drafting experimental accessibility improvement designs based on the theoretical apartment archetypes to address these issues, again informed by a review of related literature. This provided a picture of the usability and adaptability of the theoretical type apartments. Finally, the designs were applied to a sample of actual apartments to evaluate the applicability of the designs to non-theoretical cases. This evaluation included both quantitative and qualitative elements in that although the primary question was whether the designs could be applied as such or not, the effects of making certain compromises were also considered (section 3.2.3). For details on the above process, see section 3.2.1.

The adaptability of existing building floors to assisted living group homes for older people (section 3.4) was evaluated through a large-scale muilti-case study. In this, the spatial properties of existing group home units were systematically compared to the potential spaces available on apartment building floors. This was achieved by matching the recurring connectivity graphs for existing apartment building floors and group home units, after which adaptability could be assessed statistically based on the recorded dimensions present in both. All in all, the approach was much more straightforwardly quantitative than that employed for apartment buildings. Still, accepting parametric design as a form of design, this method could also be considered research by design. For details on the above process, see section 3.4.1.

2.2.2. The concept of a space in renovation

During the research it became clear that when contemplating refurbishment or repurposing multiple different ways of defining a space must be considered. In the context of renovation, the concept of a space is affected by both the structural properties of the target building(s) as well as the goals and comprehensiveness of the renovation. The choices made regarding this definition determine the kinds of adaptations which can be considered as well as the ways available for doing so. To enable comprehensively addressing the types of renovation included in this research, the following three ways of defining a space were included: **functional spaces**, **physical spaces,** and **potential spaces** (see figure 5 and description below).

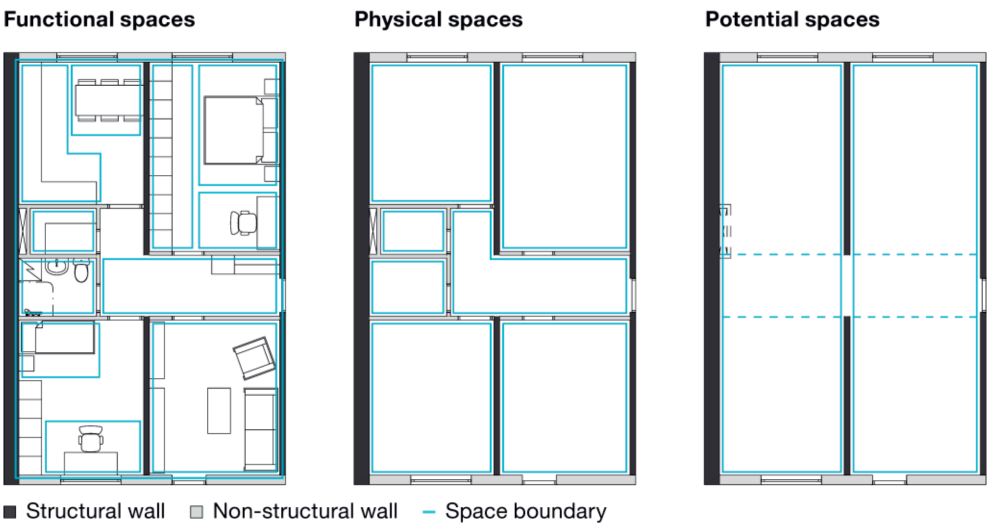


Figure 5. Different ways of defining spaces used in this research. Example using a structurally and spatially typical Finnish 1970s apartment.

Functional spaces are defined by the use of the physical environment, and based on the idea that a space doesn't need to have physical boundaries such as walls to exist (see e.g. Üngür, 2011). Such a non-physical boundary could be for example the distinction between a workspace and sleeping area in a bedroom, as in figure 5, or a shared living room and an adjacent open kitchen and dining area in a group home. On the other hand, a functional space might span the area of multiple adjacent physical spaces, e.g. an entire apartment. In either case, the definition of a space is formed as a mental and functional construct not necessarily tied to any material constraints. In this dissertation this concept is used to examine overall apartment building layouts, and to assess area requirements for the functions in existing assisted living group homes in article I.

Physical spaces are perhaps the most obvious and straightforward way of determining what constitutes a space. They are defined by the physical form of a building as it currently is, as rooms defined by floors, ceilings and structural as well as non-structural walls. Here a space conforms to a clear volumetric, physical enclosure. This concept is used to examine apartments in existing apartment buildings in articles II and III of this dissertation.

Potential spaces are in principle defined by a physical enclosure but ignore any current non-fixed elements such as non-structural partition walls. This concept is useful when considering comprehensive renovation, where space boundaries can be reasonably reduced to the most difficult to modify parts of a building frame, typically comprising structural and façade walls as well as floors. On the other hand, if specific requirements for the spaces to be created through renovation are known, they can also be included as defining criteria for potential spaces. In figure 5 the addition of a central corridor is presented as an example of such a requirement. This concept is used to examine apartment building floors as targets for repurposing in article I of this dissertation.

2.3. Research materials

2.3.1. Existing apartment building stock

The primary research material for studying the properties and potential of the existing apartment building stock was collected from the archives of the Housing Finance and Development Centre of Finland (ARA). The material consists of architectural drawings (site plans, floor plans, elevations, etc.) used to apply for state-supported construction loans. The full sample contains documents for 320 Finnish multi-story apartment buildings comprising 8745 apartments from the years 1968–1985.

As noted in section 1.4, the 1970s were a decade of massive, repetitive apartment building production in Finland. In this research, 1968 was chosen as the specific starting year for the sample because that was when the Finnish National Housing Board (Asuntohallitus) first officially recommended the use of prefabricated, standardized building components when it would be financially advantageous taking into account the place of construction (Korpivaara-Hagman, 1984). This led to a great degree of homogenization in both dimensioning and product use in construction. At the other end, 1985 was when the national housing programme for the years 1976–1985 finished, coinciding with a new law on improving housing conditions and increasing resident participation (Asuntohallitus, 1984; Valtion asuntorahasto, 1999). It should be noted that due to the nature of the material, the projects were picked based on the year when they were granted a loan, not on their year of completion or necessarily even construction. This means that even though there is variation in the actual age of the buildings compared to their nominal year in the study, the cases are accurate representations of current design practice for their recorded time.

Overall, the sample contains buildings from 51 cities, with the majority (260, 81%) being from 43 districts in the 15 cities that participated in ARA's Development Programme for Residential Areas 2013–2015. Within these 15 cities, geographical coverage of the sample was maximized by including buildings from each district with ones matching the studied time period and building type. Annual coverage was maximized by balancing the selection as much as possible throughout the chosen year range, although with a slight emphasis on the 1970s corresponding to the highest construction volumes. Furthermore, a ratio of 3:1 between slab and tower blocks was aimed at to correspond with the distribution among all contemporary publicly funded buildings (ARA, 2013). The final 60 buildings were selected from the archives at random with the criteria of falling within the selected timeframe. The purpose of this random sampling was to form a comparison sample for the material from the initial 15 cities, used in work preceding this dissertation, and through that evaluate the representativeness of that sample in relation to the wider national stock. For the research included in the dissertation the samples were merged to increase overall sample size, as no difference was found between them to prevent doing so. The locations of all cities included in the sample, as well as the number of cases in each, are presented in appendix A.

Aside from the above, no further characteristics such as tenure type, target demographic, or construction company were considered when collecting the sample. For the purposes of this research, the sample was found to be very highly representative of contemporary construction even when taking the above into account. The generalizability of the sample, and of the results based on it, is discussed in section 4.3, as well as in the included articles, mostly II and IV. Due to limitations in the original material, such as structural materials not being distinguishable, and specific requirements of the conducted research, some parts of the research used smaller subsamples of the above full set, as described in table 2.

Table 2. Samples of drawings for existing apartments used in the research.

Sample	Sample specifications and use cases
320 buildings, years 1968–1985	Full primary research sample as described in text. – Defining recurring apartment types (article II).
276 buildings, years 1968–1985 [a]	Buildings where studied structural properties identifiable in drawings. – Defining typical structural systems (article IV).
260 buildings, years 1968–1985 [a]	Buildings from the 15 cities in ARA's Development Programme for Residential Areas 2013–2015. – Forming accessibility improvement models (article III).
105 buildings, years 1970–1979 [a]	Slab blocks with at least two stairwells and a straight building mass. – Assessing adaptability into assisted living group homes (article I). – Defining typical dimensions of existing spaces in apartment buildings (article I).
216 apartments, years 1968–1985	Sample of owner-occupied apartments from Etuovi.com (2014). – Assessing the effect of tenure type on apartment designs (article II).
9 apartments, years not recorded	Sample of apartments from Tampere not included in any of the above. – Testing accessibility improvement models (article III).

[a] Subsample of the full primary research sample.

In addition to statistical data from e.g. Statistics Finland, the most notable supplement to the drawing material described above was ARA's Register of Real Estate for the years 1949–2013 (ARA, 2013). This is a database that contains information such as construction year and types of apartments for all publicly financed housing projects within the time period. The information was used primarily to evaluate how well the research sample represents the entire corresponding building stock (section 4.3.1).

2.3.2. Existing assisted living group homes

The primary research material for studying the spatial properties present in assisted living for older people was collected from the building control departments of the three largest cities in Finland: Helsinki, Espoo, and Tampere. To focus on current and recent practice, the sample was restricted to cases either built or comprehensively renovated during or after the year 2000. Additionally, only cases with three or more floors and an urban location were included, to account for the rapid urbanization of the country and the restrictions such an environment places on design. Within these criteria, the sample contains all facilities listed in the above cities' online information channels for senior housing at the time of sampling in October 2015, for which material could be found in the respective building control departments' archives. A recheck was conducted in May 2020, confirming that all of the included facilities were still operational. Furthermore, related Finnish legislation and design guidance was reviewed without finding any changes likely to have affected the applicability of the sample (section 4.3.1).

The total number of assisted living facilities included is 30, of which 12 are in Helsinki, 12 in Espoo, and 6 in Tampere (see appendix B for a list). Together these facilities comprise 130 group home units for older people, in which there are a total of 1589 group home apartments. The material consists of architectural drawings such as site plans, floor plans, sections, and elevations used to apply for building permits. The drawings used in the research were primarily the newest ones. However, since approximately half of the facilities had been constructed before the year 2000, in those cases older drawings were also referenced to ascertain the extent of the renovations conducted and thus suitability of the project to be included in the sample.

3. RESULTS AND DISCUSSION

In accordance with the research questions (section 1.4), this dissertation addresses the potential for ageing at home in the Finnish apartment building stock through the stock's need and potential for adaptation. Thus the research contribution includes a description of the buildings as originally designed (disregarding possible renovations since the creation of the research material). Based on this, the buildings' spatial suitability for housing the ageing population both as is and with different levels of modifications is assessed. In addition, the methods for each step of the above process are presented and discussed.

This section begins with a description of the original structural and spatial characteristics of the existing apartment building stock to illustrate the initial situation (section 3.1). Following the above, the use and adaptation potential of the buildings is first discussed from the perspective of independent housing on the level of single apartments (research question 1, section 3.2). Next, the spatial characteristics of existing assisted living group homes are examined (section 3.3). Finally, the repurposing potential of existing apartment building floors into assisted living group homes is assessed (research question 2, section 3.4).

3.1. Characteristics of existing apartment buildings

This study focuses on the usability and adaptability of apartments and residential floors. Thus the characteristics of existing apartment buildings presented here do not concern basements—whether below or above ground—or attics unless otherwise noted. Due to the predominant structural system of load bearing crosswalls (section 3.1.2), observations regarding spatial dimensioning, although made based on residential floors, would also largely apply to the basement floor below them. Correspondingly, in future work the current dataset and typology could be extended to also cover those using the same methodology. These possible avenues of further research, among others, are discussed in section 5.2.

3.1.1. Assessment methodology

With a topic as extensive as characterizing a building stock, it is essential to first clearly set one's specific perspective on the topic. This directly determines the information required to characterize the stock, and thus the type and amount of material needed. It is also necessary in order to form a useful typology (section 2.1). Therefore, an overview of the initial data collection and processing steps used in the current research is provided here as background for the description of the subsequent analysis. It is also included in figure 6, which summarizes the methodological structure of the characterization process for existing apartment buildings.

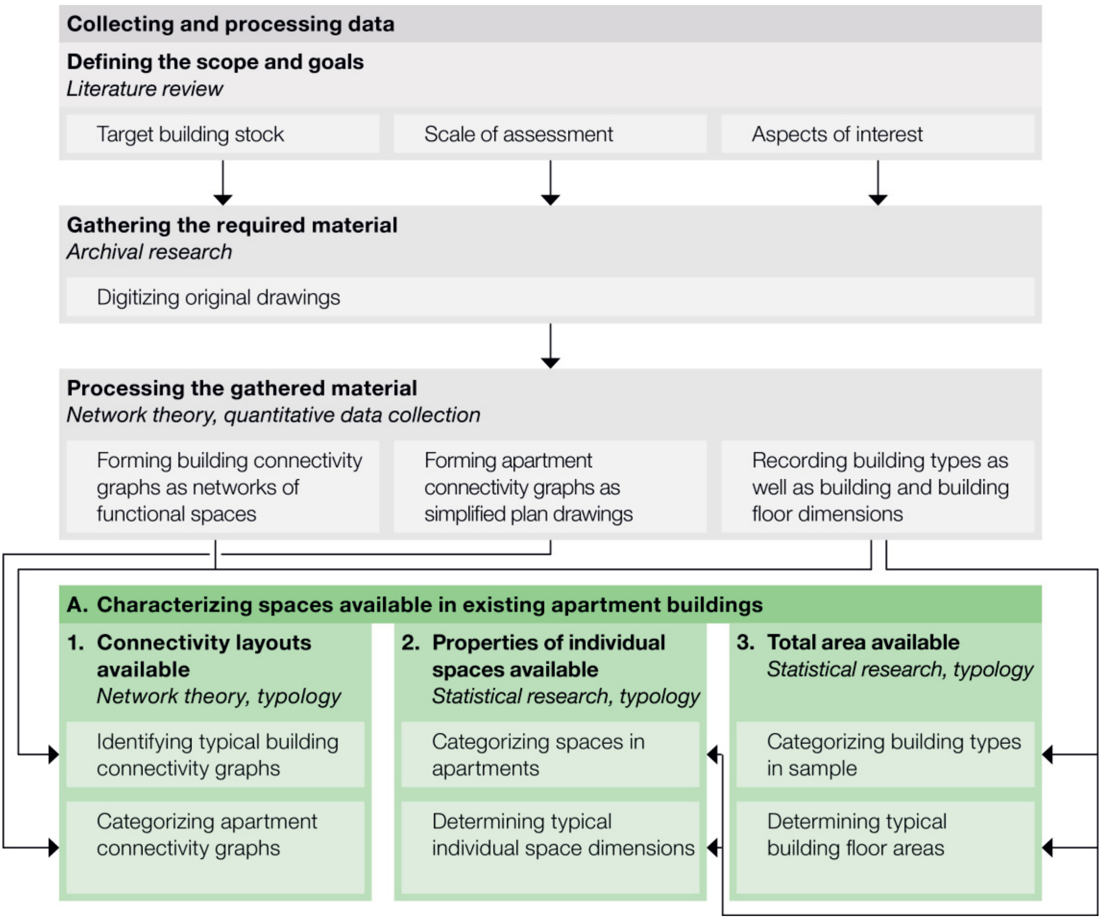


Figure 6. The process of determining the characteristics of existing apartment buildings. Research stages preceding the topic of the current main section are presented in gray.

As discussed in section 1.4, in the current research **defining the scope and goals** entailed specifying the target building stock (Finnish multi-storey apartment buildings from the 1970s), the scale of assessment (individual buildings), and the aspects of interest (spatial structure and space specific spatial properties). After carefully defining these boundaries, resources required for **gathering the required material** could be minimized without compromising the usefulness of the sample. This material collection consisted of archival research (see section 2.3.1) in the form of digitizing original hand-drawn architectural drawings. The next and final foundational step was **processing the gathered material** into a form that suits the following analysis. As established in section 2.2.1, this comprised forming connectivity graphs of the spatial networks present and, connected to these, recording certain properties of both single buildings and single spaces. For the goal of assessing the spatial structures of the studied buildings, connections between spaces were examined at two levels for all buildings in the full primary research sample (N=320): the whole building, and individual apartments.

Firstly, the interior layouts of whole buildings were mapped as simple connectivity graphs of functional spaces (for the definition see section 2.2.2). Since the current research focuses on apartments and residential floors, all non-corridor common areas (laundry, storage, etc.) adjacent to each other were treated as single functional spaces. Likewise, only the entrances to apartments were noted as their interior configurations would be studied separately. Though differing in the level of abstraction, the basic principle is similar to earlier work by e.g. Sting (1975, cited in van Leusen, 1994, pp. 46–51), who described buildings in terms of 'access units' formed by groups of apartments. Specifically, in both some groups of spaces are consolidated into singular entities to simplify the description of the larger whole. Through the above process, connectivity graphs similar to the theoretical example in figure 7 were produced.

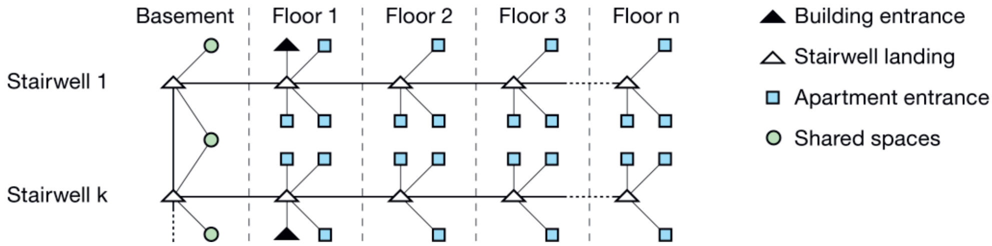


Figure 7. Connectivity graph for a typical apartment building with n floors and k stairwells. Single stairwell buildings were also included, although two stairwells are presented here for illustrative purposes. Depending on the building the ground floor with the entrance can be either the basement or floor 1, or the entrance can be halfway between those two.

Secondly, separate connectivity graphs were formed for each distinct apartment plan found, similarly to many earlier works on housing typology (sections 2.1 and 2.2.1). In contrast to creating only all-encompassing building or building floor scale graphs, this approach allows easily comparing individual apartments or apartment types, the results of which can then be aggregated to the broader scales. Doing the opposite through subgraphs, while potentially beneficial for future work, would add a disproportionate amount of complexity considering the division of the current research into (1) single apartments and (2) buildings as reserves of individual spaces. To accommodate more detail than a simple network of nodes, the graphs for apartments were constructed as simplified scaled plan drawings, in which only the elements relevant to the current enquiry were visible. These include separate rooms (i.e. nodes) and the connections between them (edges) along with the locations of windows and structural/non-structural walls. As all apartments in the sample were single-storey, connections were always either doors or doorways, never stairs. Some examples of the produced plan drawings are presented in figure 8. Embedded in the simplified plan drawings, additional space specific properties such as the types of rooms (kitchen, other habitable room, bathroom) and their dimensions were also recorded. This extension was similar to, though obviously not based on, the one Herthogs et al. (2019) later envisioned as a complementary component to their graph based building layout assessment method.

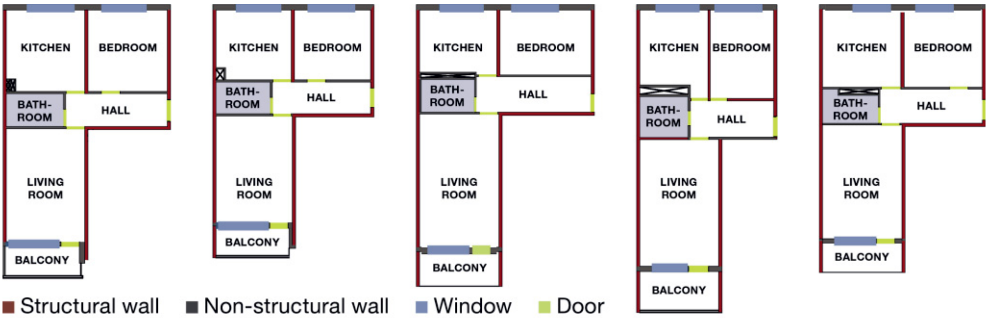


Figure 8. Examples of simplified plan drawings. Similar drawings were created for all distinct apartments in the primary research sample.

Finally, for each of the 320 buildings overall dimensions and building type were recorded. The dimensions recorded at this stage included interior building width and depth, and the number of residential floors. For buildings with varying depth, average values were used. For building type, a distinction was simply made between slab and tower blocks.

It should be noted that the concept of 'building type' is not entirely unambiguous. For example, the word 'tower' implies that a building is tall relative to its footprint, and correspondingly has a small footprint relative to its floor area. At the same time it is possible for one building to have three floors and another to have ten, the only difference between them being the number of repeated middle floors. To a degree the dimensions of the footprint can also vary, a single stairwell tower block potentially being more oblong than a deep two stairwell slab block. Moreover, if a slab block is understood to consist of multiple separate stairwell units within a shared envelope, how does one categorize a building consisting of only one such unit with no other differences? Ultimately the distinction depends on the aims of the categorization.

In the current research, the distinction between slab and tower blocks was based on whether there were multiple stairwells in the building, or could be through duplication of the existing design without altering the floor layout. Therefore each building with multiple stairwells was considered a slab block, as was each single stairwell building with windows of habitable rooms on only two opposite sides, and the rest were considered tower blocks. This was done instead of simply noting the amount of stairwells due to the impact the placement options of habitable rooms have on the apartment layouts present. There were no side corridor or central corridor buildings in the sample.

For **characterizing the spaces available in existing apartment buildings** the first phase (**A1** in figure 6) consisted of determining the typical **connectivity layouts available**, i.e. examining the collection of connectivity graphs produced earlier to identify recurring layouts. For whole buildings there was no need for categorization aside from noting the number of stairwells, as practically all cases corresponded to the layout presented in figure 7. For individual apartments, the connectivity graphs represented by the simplified plan drawings (figure 8) were categorized into a layout based hierarchy. The first level of categorization was formed by the number of habitable rooms, similarly to e.g. Ju et al. (2014). Only apartments with 1–4 rooms and a kitchen were included, since larger ones were extremely rare (for details see section 3.1.4), and thus virtually guaranteed to yield no certainly definable types. Forming the second level of categorization was guided by renovation potential being a key motivation behind the whole characterization process. Specifically, this categorization level was based on the locations of habitable rooms, due to the difficulties inherent in changing those locations. Most of these rooms are surrounded by at least three walls that are either structural, exterior, or both, resulting in their dimensions being quite fixed, and their locations even more so (for details see section 3.1.2). The third and final categorization criterion was the location of the bathroom. Like habitable rooms, the bathroom is typically difficult to relocate or resize. Although the bathroom is mostly not surrounded by structural walls, it does usually determine the location of the main plumbing stack. Furthermore, many changes to the layout that might be done during renovation, such as relocating drainpipes, would affect the floor and thus any spaces below. The above process resulted in a selection of systematically categorized recurring apartment layouts—apartment types.

These apartment types thus determined were and are dimensionless, i.e. defined by their layout but not their dimensioning, corresponding to a definition of type introduced by Klein already in 1928 (cited in Van Leusen, 1994, pp. 30–31). Also similarly, within the types individual instances still exhibited their specific dimensions. For each apartment type, approximate typical dimensions as well as variations thereof could be determined by overlaying the simplified plan drawing of each individual instance, including duplicates of instances (figure 9, left). To enable this process asymmetric layouts such as the one in figure 9 were rotated and/or mirrored as needed. Using the typical dimensions, representative theoretical apartment floor plans were then developed (figure 9, right), exemplifying each apartment type while also displaying the common variation ranges found among individual instances.

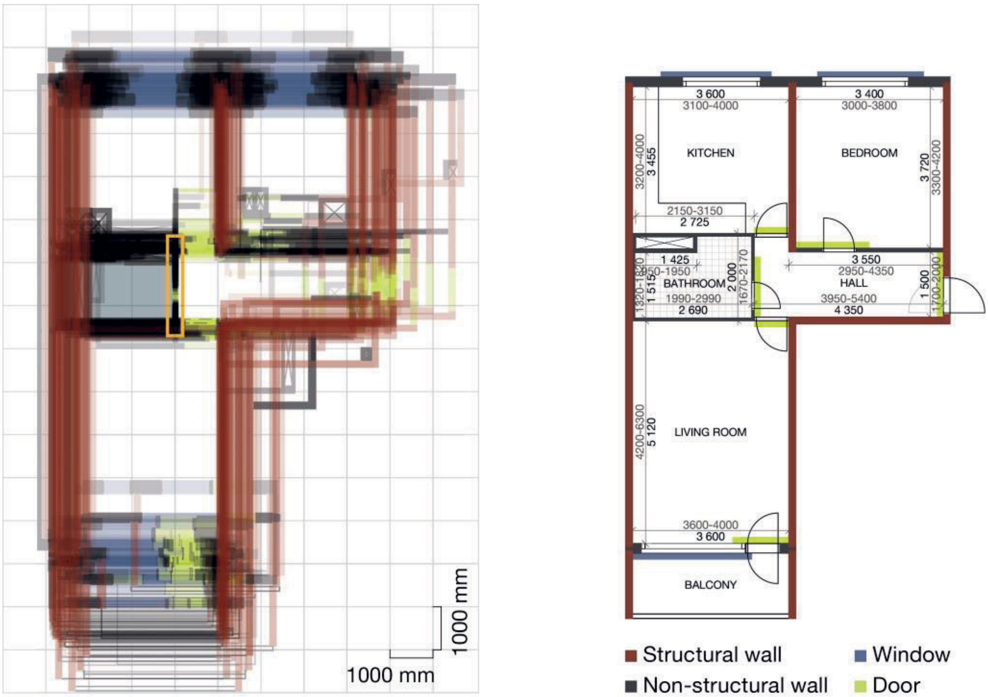


Figure 9. **Stack of simplified plan drawings and the resulting typical plan for an apartment.** Plan drawings have been aligned based on the circled bathroom wall. On the right, the typical dimensions and locations of rooms and other elements are presented as well as their common variation ranges. (Adapted from article II and Kaasalainen (2015, p. 188).)

The second phase (**A2**) of the characterization process focused on the **properties of individual spaces available** in the studied buildings. The apartments in the studied stock have very clear room definitions, where each room corresponds to a single main function, in addition to which the dimensions of most rooms are rather fixed (section 3.1.2). Hence, the primary frame of observation here was single existing physical spaces (for the definition see section 2.2.2). For increased accuracy the approximate room dimensions obtained in the previous phase were supplemented by examining all of the rooms in a subsample of buildings (n=105, all slab blocks from the years 1970–1979) from the full primary research sample (N=320, years 1968–1985). A subsample was used to limit the amount of manual measuring work. Due to the uniformity of dimensioning within the stock, resulting from the construction guidelines and practices of the time (sections 3.1.2, 3.1.4, and 3.1.5), limiting the size of the sample was expected to have a negligible effect compared to using the full sample. A comparison between the earlier approximated figures and the new more precise data ended up supporting this assumption.

The above provided a description of the typical dimensions, and their variation ranges, for individual existing physical spaces. After this, the dimensions of potential spaces defined by the structural building frame could be determined by examining these dimensions together with the apartment types defined in phase **A1**, which contained the typical locations of structural walls and individual rooms.

The third and final phase (**A3**) of the characterization process returned to the broader building level to determine the **total area available** on typical building floors, motivated especially by potential comprehensive repurposing measures. Utilizing the building and building floor level data recorded earlier, this was a simple matter of statistically determining typical values and variation ranges. Typological classification was present in this phase too to the straightforward extent of again distinguishing between slab and tower blocks.

3.1.2. Structural systems

Within the studied building stock a crosswall frame is by far the most common structural system used. In the research sample used in this dissertation the crosswall system covered 90.9% of the buildings examined in article IV (n=276, years 1968–1985) and 100.0% of those in article I (n=105, years 1970–1979). The most extensive previous survey with a sample of 270 buildings by Mäkiö et al. (1994) recorded a share of 61.1% for the years 1960–1975 and 84.4% for 1970–1975 (see article IV for details). In this style of construction a building is supported by structural walls located at the ends of a slab block, and further structural walls within the building that are parallel to those. In tower blocks the principle is adapted so that each habitable room is bordered by at least two parallel and opposite structural walls. Figure 10 illustrates the structural principle of a crosswall frame for typical Finnish slab and tower block floor layouts from the 1970s. Although not a spatial property per se, the structural system of a building often has a fundamental effect on the actual spaces present and possible. Therefore it is something that must be considered here, especially when the examination of spaces includes the potential for changing their boundaries.

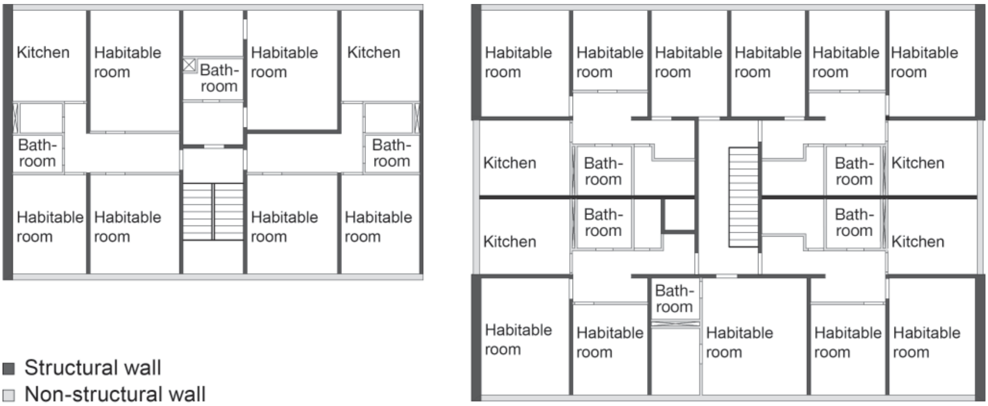


Figure 10. Typical locations of structural and non-structural walls in slab blocks (left) and tower blocks (right) in the studied building stock.

The impact that having a crosswall frame has on the adaptability of a building depends greatly on how many of the interior walls are structural. In earlier structural systems of the studied era, such as the Finnish large panel one used from the early 1960s to 1975, all partition walls were structural (Mäkiö et al., 1994). In the late 1960s the Finnish concrete industry started the development of the BES system ('BetoniElementtiStandardi, Finnish for 'concrete element standard'), which was first utilized in apartment building construction in 1971. A major change in BES compared to previous construction was the introduction of hollow core slabs (or more rarely Nilcon or U-slabs). This allowed greatly increased continuous floor spans and eliminated the need for structural partition walls within apartments. (Hytönen and Seppänen, 2009.)

Based on the cases examined in this dissertation, however, the use of structural partition walls was still very common even after the introduction of the BES system, at least in publicly financed production. Of the 105 buildings from the 1970s sampled for article I, all partition walls between habitable rooms were structural in 77.1%. Similarly, of the 276 buildings from the years 1968–1985 studied for article IV, only 30.8% used hollow core or Nilcon slabs (none used U-slabs), thus not needing structural walls within apartments. As a result, changing the original room sizes is often difficult since each habitable room is usually bordered by at least two structural partition walls and an exterior wall. Barring additions to the building volume or major structural works, typically the only direction available for expansion is towards the hall or a possible adjacent bathroom. Correspondingly, a difference between physical and potential spaces (see section 2.2.2) typically only exists in the depth dimension.

All buildings sampled for article IV, where the required dimensions could be determined (n=266), had a floor height of 2800 mm. Due to different floor structures the open room height (excluding any non-structural layers) varied between 2480 and 2650 mm with a median of 2600 mm. Current Finnish regulations for new apartment building construction demand a floor height of at least 3000 mm and an open room height of at least 2500 mm (A1008/2017). Thus the existing room heights should pose no usability issues. However, should the height be further reduced due to e.g. the need for additional sound proofing, possible ventilation duct retrofits might become more difficult.

3.1.3. Building scale, layouts, and connectivity

The number of residential floors per building in the primary research sample ranges between 2–9 with a median of 3. In general, slab blocks tend to be lower than tower blocks: slab blocks have a range of 2–8 residential floors and a median of 3, while tower blocks have a range of 2–9 and a median of 6. For typical gross internal area per floor the situation is the opposite: for slab blocks floor area ranges between 170–1130 m^2 with an interquartile range of 310–610 m^2 and a median of 440 m^2, for tower blocks between 200–860 m^2 with an interquartile range of 200–370 m^2 and a median of 350 m^2 (figure 11). There are no split level buildings in the sample, nor any multi-storey height rooms aside from stairwells. Thus each floor covers the full horizontal extent of the building footprint.

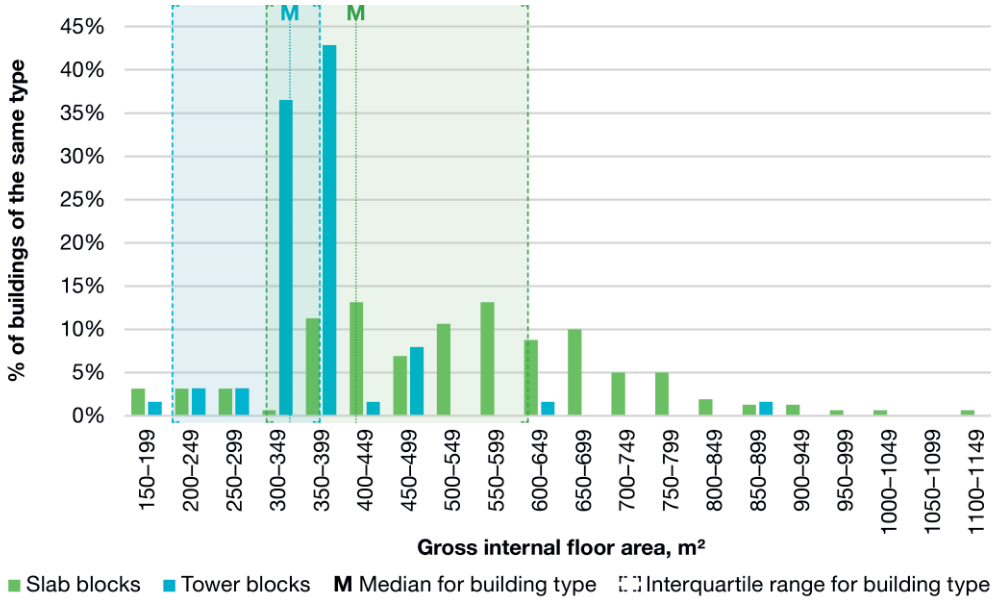


Figure 11. Distribution of single floor areas in the studied apartment buildings. Buildings include all in the primary research sample (N=320) for which the data was recorded for article IV, i.e. 160 slab blocks and 65 tower blocks.

When it comes to overall spatial layouts, both slab and tower block in the studied stock exhibit the same clear division of semi-public and private spaces: shared functions such as storage, laundry room, and sauna are located in the basement (below ground or on the ground floor), or more rarely in the attic. The ground floor may also contain some commercial functions. The vast majority of residential floors have only apartments. Furthermore, all residential floors of a building are typically identical, as tends to be the case in construction striving for cost efficiency (Van Leusen, 1994, pp. 137–140). The main exceptions to this are buildings with some ground floor apartments. Even then, the structural layout is mostly identical to the floors containing only apartments, with some spaces merely allocated to other functions. Shared balconies or similarly placed terraces suitable for spending time are rare. In addition to ones meant for airing carpets, which are often accessed from a stair landing between floors and thus not (wheelchair) accessible, these are usually connected to the sauna or club room. While shared balconies and terraces were not studied in detail in the current research, these too are likely to have accessibility issues related to e.g. dimensioning, thresholds, and lack of glazing, similarly to those in apartments (section 3.2.3). Thus modifications to them should also be taken into consideration in any concrete renovation projects due to the significant impact easy access outside can have on resident health and wellbeing (e.g. Mäntylä et al., 2011, p. 10; Mooney and Nicell, 1992, p. 29).

The layouts of residential floors are very simple and uniform in both apartment building types. The main entrance leads directly into the stairwell and apartment entrances are clustered on compact landings without additional corridors. Multiple stairwells in slab blocks are only connected on the non-residential floors. Moving onwards, nearly every apartment is organized around a central hall, which practically always connects directly to all further rooms. The only exceptions to this are some bedrooms being accessed through the kitchen or the living room, and kitchenettes in studios and some two room apartments being accessed through the main habitable room. As shown in figure 12, this means that in terms of spatial connectivity the existing layouts are very shallow, 'bushlike' (Klarqvist, 1993, p. 11), on the scale of the whole building, individual floors, and individual apartments.

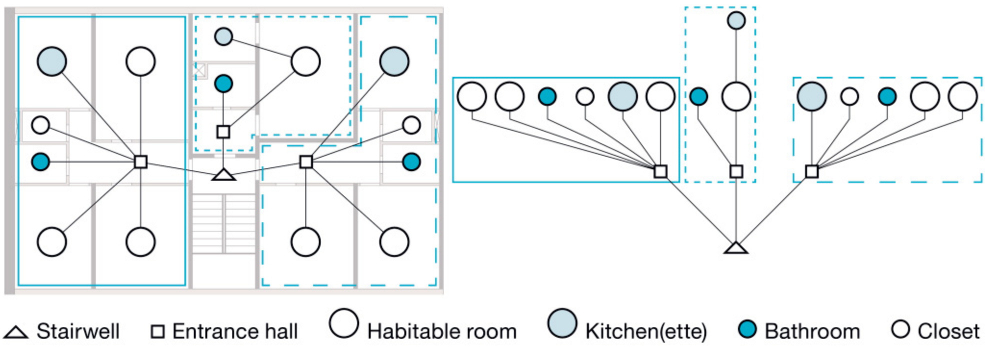


Figure 12. Connectivity graph (left) and justified plan graph (right) for a typical apartment building floor. While the example provided is of a slab block, tower blocks exhibit identical connectivity principles with a single stairwell and central hall apartment designs (see figure 10).

Zhao (2016, p. 128) notes that such dwelling configurations are common in post-war mass housing in general, and attributes the popularity of the layout to the prevalence of nuclear families, presumably on the basis that such a living situation requires a number of private, independent rooms. In connection to criticizing the suitability of these layouts to the variety of modern living arrangements, they also highlight the flexibility of the layouts for spatial connectivity rearrangement. Indeed, as figure 12 illustrates, in a typical floor layout there is very minimal need to go through spaces to reach further ones. Correspondingly, from the perspective of access this facilitates easy adaptability to different uses (Herthogs et al., 2019; Leupen, 2006). Both the building and apartment layouts also support easy wayfinding due to their simplicity, although the general monotony does also mean that e.g. color and material choices become more important in forming distinguishable locations, especially for residents with cognitive issues (Rakennustietosäätiö RTS, 2013, p. 10; Sievänen et al., 2007, p. 9).

Concerning vertical connectivity, it is notable that very few of the buildings originally had elevators, and often still don't (Helminen et al., 2017, p. 48), which carries obvious implications to many residents' ability to leave their apartment. Furthermore, in many buildings the actual floors are a flight of stairs up from the entrance (see figure 12), which poses additional challenges for adding an elevator. Addressing this issue is vital, or even the best of renovations inside apartments may still leave residents practically trapped in their dwelling (Verma, 2020). Since the problem has long been well acknowledged (e.g. Pekka et al., 2008; Verma et al., 2012), if not sufficiently dealt with, multiple well studied and widely implemented solutions exist for elevator retrofits. These solutions range from adding an elevator in between the (narrowed down) stair flights to constructing a new shaft outside the original building envelope (Rakennustietosäätiö RTS, 2019). In the cases studied here, although the difficulty and cost would vary greatly, all of the typical building designs could be modified to accommodate an elevator retrofit, at least given sufficient space in front of the building or the ability to take the required space from the apartment zone. Noting this and the existence of well known solutions, the issue is not addressed in detail in the current study.

3.1.4. Individual apartments

Although there were no official standard building plans, the Finnish apartment production of the studied era was in practice highly standardized. After the Tax Relief Act of 1962, the distribution of apartment sizes was guided by the fact that to receive the tax relief, the number of apartments under 50 m² in a project could not be greater than a third of all apartments (Mäkiö et al., 1994, p. 255). Despite this, the publicly funded apartment stock of that time is heavily weighted towards small apartments in terms of room count. In both the primary research sample of apartments (N=8745) and a comparison sample from ARA's Register of Real Estate (n=128 844), studio and two room apartments constitute approximately two thirds of all apartments (see table 3).

Table 3. Apartment room count distribution in publicly funded multi-storey apartment blocks from the years 1968–1985. The figures on the top row correspond to all habitable rooms other than kitchens, as is the typical notation in Finland.

	1 room	2 room	3 room	4 room	5 room	6 room	Total
Primary research sample, 320 buildings							
Number of apartments	1 854	3 932	2 494	455	10	0	8 745
% of all apartments	21.2%	45.0%	28.5%	5.2%	0.1%	0.0%	
ARA's Register of Real Estate, 3158 projects (ARA, 2013)							
Number of apartments	24 106	62 890	35 118	6 380	309	41	128 844
% of all apartments	18.7%	48.8%	27.3%	5.0%	0.2%	0.03%	

In addition to apartment room counts, there were also guidelines for recommended floor areas for each room count in publicly subsidized construction. For apartments with one, two, three, four, or five rooms (excluding the kitchen) the respective figures were 30–35, 45–65, 65–80, 80–100, and 100–120 m² (Mäkiö et al., 1994, p. 194). Some recommendations provided even higher minimums, such as 55–65 m² for two room and 90–100 for four room apartments (Suomen Asuntoliitto, 1969, p. 15). Combined with the above observation about room count distributions, it is clear that especially two room apartments were quite generously dimensioned compared to current Finnish production. As only a third of the apartments were allowed to be under 50 m², and one room apartments already covered a fifth, at least two thirds of two room apartments would have had to exceed 50 m².

Publicly subsidized production comprised a significant part of the total production during the studied era at 51.0% for 1968–1985 and 56.2% for 1970–1979 (Laine, 1993). The rest, being privately financed, was not bound by the above restrictions. However, private production largely followed the same practices and guidelines regardless (Keiski, 1998, p. 40; Neuvonen, 2006, p. 210). In fact, according to Mäkiö et al. (1994, p. 46) a difference was often found only in the materials, which Neuvonen (2006, p. 210) further specifies into the finishing materials used. Neuvonen (2006, p. 180) also points out the widespread use of modular grids as a factor further promoting uniformity of dimensions in all construction regardless of financing method. This view is supported by Korpivaara-Hagman (1984).

To further examine the differences in apartment design between financing methods, in the current research a sample of 355 172 publicly funded apartments from ARA's Register of Real Estate (2013) was compared to statistics on contemporary privately financed production (Kakko, 2011; Laine, 1993; Official Statistics of Finland, 2013). The comparison revealed an average difference of only 0.7 m² in apartment floor area. The difference was not constant, being notably larger in the beginning of the era as well as towards the 1980s, and smallest around the peak construction years of the mid-1970s (for details see article II, p. 223). Therefore, an apartment size difference between the financing methods clearly exist, but it is inversely correlated with the amount of apartment production, suggesting a high degree of uniformity in the stock overall.

Some of the difference between the financing methods may also have been explained by different shares of rental and owner-occupied apartments, the latter of which according to Laine (1993) have a higher share of larger, three or four room apartments. This claim is supported by a comparison sample of 160 210 publicly funded rental apartments from ARA's Register of Real Estate (ARA, 2013) having an average room count of 2.1, which is slightly lower than the 2.2 in the primary research sample with both tenure types (for details see article II, pp. 224–225). Another comparison sample of 2000 random owner-occupied apartments from the era, 500 for each room count 1–4, provided further confirmation, showing virtually no variation in average area between different tenure types (for details see article II, pp. 225–226). Notably for the purposes of this study, all of the above strongly suggests that neither financing method nor tenure type affected the dimensioning of individual spaces or the layouts of individual apartments. Correspondingly, neither affects the use of individual rooms, as is or in adaptation, nor the use of entire floors as spatial reserves, aside from a negligible difference in the number of structural walls corresponding to the number of separate apartments in BES buildings.

The compliance with guidelines discussed above—whether strictly required or not—combined with the structural systems of the time led to a high degree of uniformity in apartment design. Within the studied primary sample of 320 buildings comprising 8745 apartments, 10 recurring apartment main types were found, further divided into 18 subtypes. These are presented in figure 13, as floor plans using typical room proportions, and as justified plan graphs describing connections between spaces. As was established in section 3.1.3, existing apartments are generally arranged around a central hall linking all other spaces, with only very rare exceptions. Following this, the connectivity layouts differ very little in anything but the number of rooms, and the hall is typically the only space connected to more than one other room.

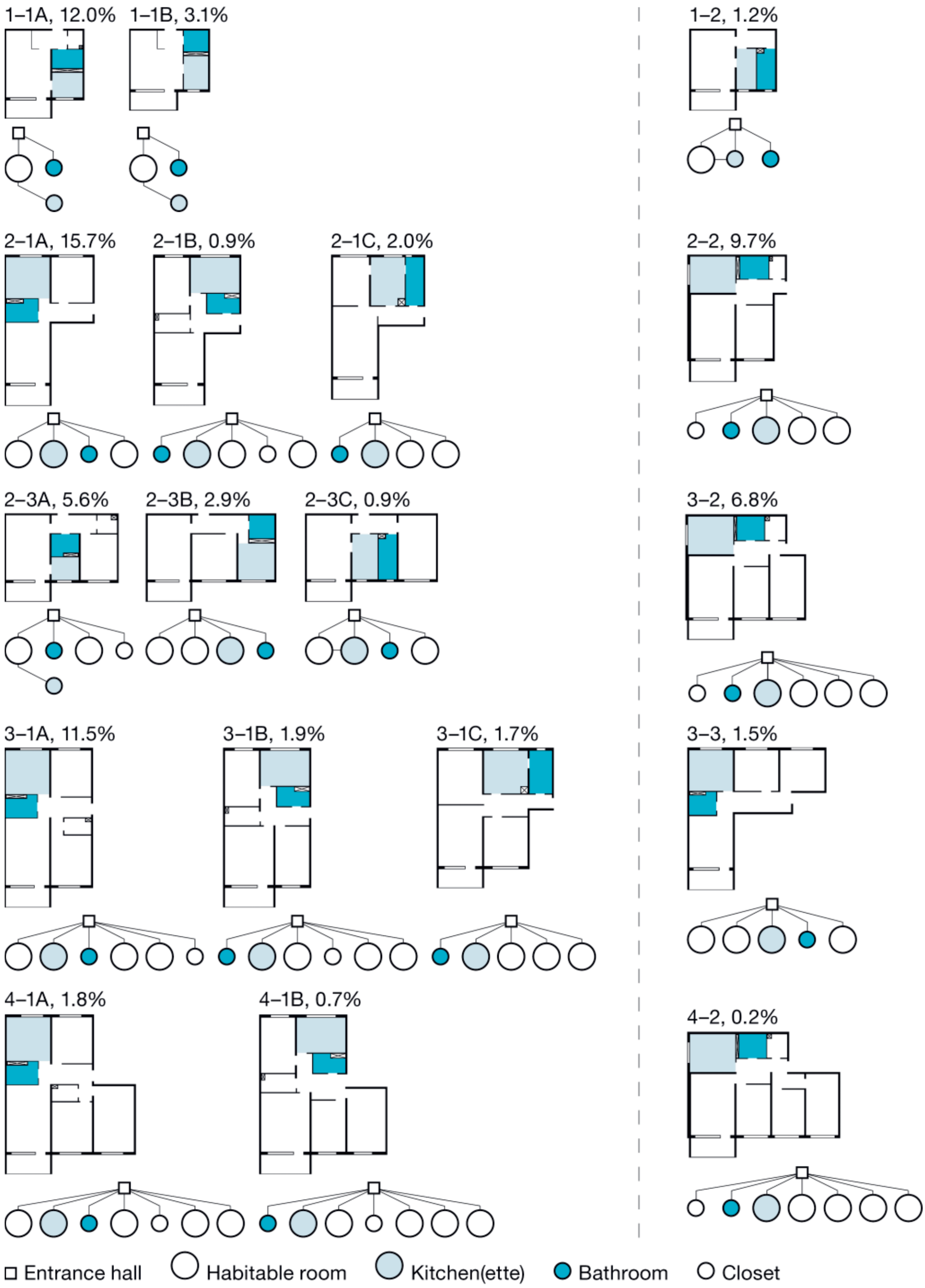


Figure 13. Recurring apartment types in the studied building stock. The percentages indicate the share of each type out of all the apartments in the research sample (total share 80.1%). Plans on the left are main types with multiple subtypes, plans on the right are main types without further subtypes. (Plans adapted from Article III.)

In addition to the obvious homogeneity in connectivity, it is clear that most apartments are quite simple variations of each other. For example, between the most common apartment types for their respective room counts, 2–1A, 3–1A, and 4–1A, the only difference in layout is the number of bedrooms attached to the hall and the presence of a walk-in closet. The same is also true for the respective –B and –C subtypes, as well as main types 2–2, 3–2, and 4–2. A layout corresponding to the missing 4–1C was not found in significant numbers in the sample, and was thus left out, but based on the patterns exhibited by the other main types it is also highly likely to exist. Thus, while unnecessary for the current purpose of studying commonly recurring apartment layouts, the present typology could be further extended to include additional existing layouts or even ones possible by altering apartment boundaries. In total, the 18 recognized apartment types cover 80.1% of all the studied apartments. As established above, statistical comparisons to the larger building stock indicate that they are also highly applicable to contemporary apartment production in general. From the perspective of evaluating usability and adaptability this offers great potential by enabling a high degree of generalizability using a relatively small number of carefully formed theoretical cases.

3.1.5. Single physical spaces

In this and the next section most of the figures presented for single spaces, both physical and potential, are based on examining spaces in slab blocks. However, as noted the same guidance and regulations were followed (section 3.1.4), and structural systems used (3.1.2), in all contemporary apartment block construction. Correspondingly, overall building form does not noticeably affect the design of individual rooms, the dimensions of which are very similar in slab and tower blocks. Thus the figures based on slab blocks are very likely to apply to the full sample of 320 buildings, and consequently to the vast majority of the studied apartment stock of Finnish post-war mass housing.

When it comes to existing physical spaces, apartments in the studied stock originally have very clear room definitions. There are virtually no open plan kitchens for example, and each room is separated by a doorway—usually with a door in it, at least originally. Each physical space has thus been designed with certain functionality in mind, and usually in accordance with quite detailed guidance and regulations (Korpivaara-Hagman, 1984; Mäkiö et al., 1994). Therefore, in addition to the repetitiveness of layouts pointed out in the previous section, there is fairly little size variation among rooms with the same functional designations.

Before 1970 the smallest allowed dimension for living rooms in publicly subsidized housing was 3300 mm, and from 1970 onwards 3600 mm (Mäkiö et al., 1994, p. 194). Since over half of the apartments produced during the decade were publicly subsidized and the same practices prevailed in private production (section 3.1.4), most apartments from the studied era have at least one fairly spacious habitable room. Typically this is the original living room. Furthermore, kitchens and bedrooms are usually also rather similarly dimensioned. This can be seen in the typical floor plans presented in figure 13 as well as in the comparison of room widths in figure 14. Of all the sampled habitable rooms other than kitchens, 99.6% were at least 2000 mm in their narrowest dimension, 93.5% at least 2800 mm, and 49.3% at least 3600 mm. For kitchens, the respective figures are 100.0%, 90.5%, and 9.9%. Combined with the clearly partitioned central hall layouts, this spaciousness and dimensional similarity makes repurposing rooms relatively easy. For example, it would be quite simple to add an open plan kitchen into the living room and convert the original kitchen into some other use. This is especially true in the most common layouts with the bathroom and thus main plumbing stack between the two rooms (see e.g. apartment type 2–1A in figure 13).

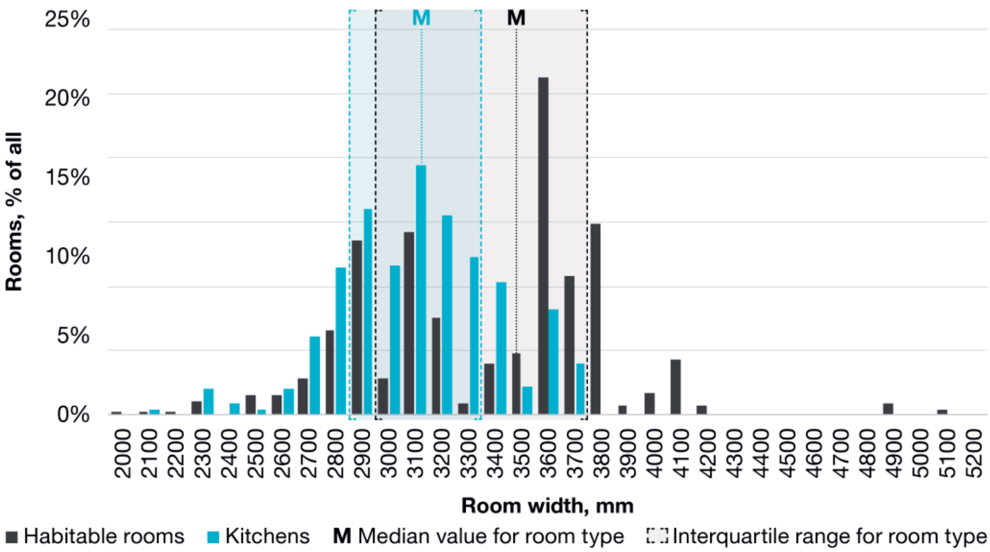


Figure 14. Widths of habitable rooms and kitchens in existing apartment buildings. Here width is the narrowest dimension of the room, regardless of its orientation in relation to the façade, rounded to the nearest 100 mm. All rooms in the sample are orthogonal, and rectangular with only occasional minor deviations. The dimensions presented are based on the 1803 habitable rooms and 568 kitchens on the 105 slab block floors used as a sample for article I. Kitchenettes are not included in the figures for kitchens.

Among existing spaces, in addition to habitable rooms and kitchens, bathrooms are of special interest. They have been singled out as the most common target of renovations in Finnish older people's households (Verma et al., 2006), and also feature prominently in research examining housing adaptations for older people in other countries (e.g. Cho et al., 2016; Fänge and Iwarsson, 2005; Niva and Skär, 2006; Pettersson et al., 2017; Thordardottir et al., 2019). The vast majority of adaptations observed in existing work consists of replacing bathtubs with showers, adding grab bars, and dealing with level differences to the rest of the apartment (section 1.3). In many cases this might be due to the labor and costs involved with changing the dimensions of a bathroom. Still, ultimately it is the dimensioning of the bathroom itself, and in some cases the ability of the surroundings to accommodate extensions, which define how useful the aforementioned adaptations can be.

In the apartments studied in this research, two general shapes for bathrooms could be found: one that is relatively close to a square (see e.g. apartment type 2–1A in figure 13), and one that is much more oblong. Based on the occurrence of the apartment types themselves, the square shape is much more common—assuming full correspondence to the apartment types, it would cover 92.9% of all bathrooms. To determine the usual dimensions and floor areas for bathrooms, a sample comprising 310 distinct 1–3 room apartments within the recurring apartment layouts was examined. Typical internal space widths for bathrooms ranged from approximately 1.4 to 3.2 meters, so that an increase in one direction usually accompanied a decrease in the other. Both extremes were also rather rare, as is to be expected considering the prevalence of square room shapes noted above. Correspondingly, although the total variation in floor area was extensive at 1.4–6.5 m², the interquartile range of 3.5–4.4 m² around the median of 3.9 m² remained fairly narrow. The above findings indicate that even though particularly difficult cases obviously exist, a majority of the apartments in the studied stock have bathrooms that are quite reasonably dimensioned. Most do, however, fall below current Finnish guidelines, which even with an optimal room shape and without extra room for a caregiver require at least approximately 4 m² of floor area (Kilpelä, 2019, pp. 100–101).

During the studied era, separate toilets were recommended only for large family apartments (Suomen Asuntoliitto, 1969, pp. 15–17) and were thus rare. In the above sample, a separate toilet was found in only 21 (6.8%) of the apartments. Including four room and larger apartments would likely raise the figure, but only slightly due to their low overall number in the stock (approximately 5%, see table 3). Aside from halls, other rooms in the apartments consist entirely of small walk-in closets, typically approximately half the size of a bathroom, corresponding to contemporary guidance (Suomen Asuntoliitto, 1969, pp. 15–17).

On the whole, most habitable rooms in the studied buildings have a reasonable amount of floor area and are wide enough to support multiple furniture layouts. This makes most of them suitable for varying individual needs as is. Moreover, most of the common layouts allow using some of this spaciousness for extending adjacent smaller rooms, i.e. the bathroom and the hall.

3.1.6. Single potential spaces

As noted in section 3.1.2, due to the prevalence of crosswall frames the dimensions of most habitable rooms can only be reasonably adjusted in the depth direction, i.e. perpendicular to the façade. Furthermore, rooms tend to already be deeper than they are wide since this creates a more efficient building footprint. Without major structural work the difference between physical and potential spaces (see section 3.1.1) is therefore most often a matter of extending the dimension that is already longest. It should, however, be considered that compared to modern central corridor designs the building plans in especially slab blocks are usually not that deep. Thus, extending the existing spaces towards the centerline of the building does not necessarily make them unsuitable for use as e.g. living rooms. Many spaces can also be merged with another one on the opposite façade to provide more natural light and thus improve resident wellbeing, enable cross ventilation, and make more room for e.g. a combined kitchen, dining area, and living room. This, of course, is usually only possible in slab blocks where apartments span from one façade to the opposite one, and to a lesser extent in corner apartments in slab blocks. Dual aspect apartments do, however, cover 54.4% of the discovered typical apartment layouts in the stock (see figure 13), making this a rather common possibility in dwellings larger than studios. Figure 15 presents an overview of the dimensions of potential spaces in the studied apartment buildings.

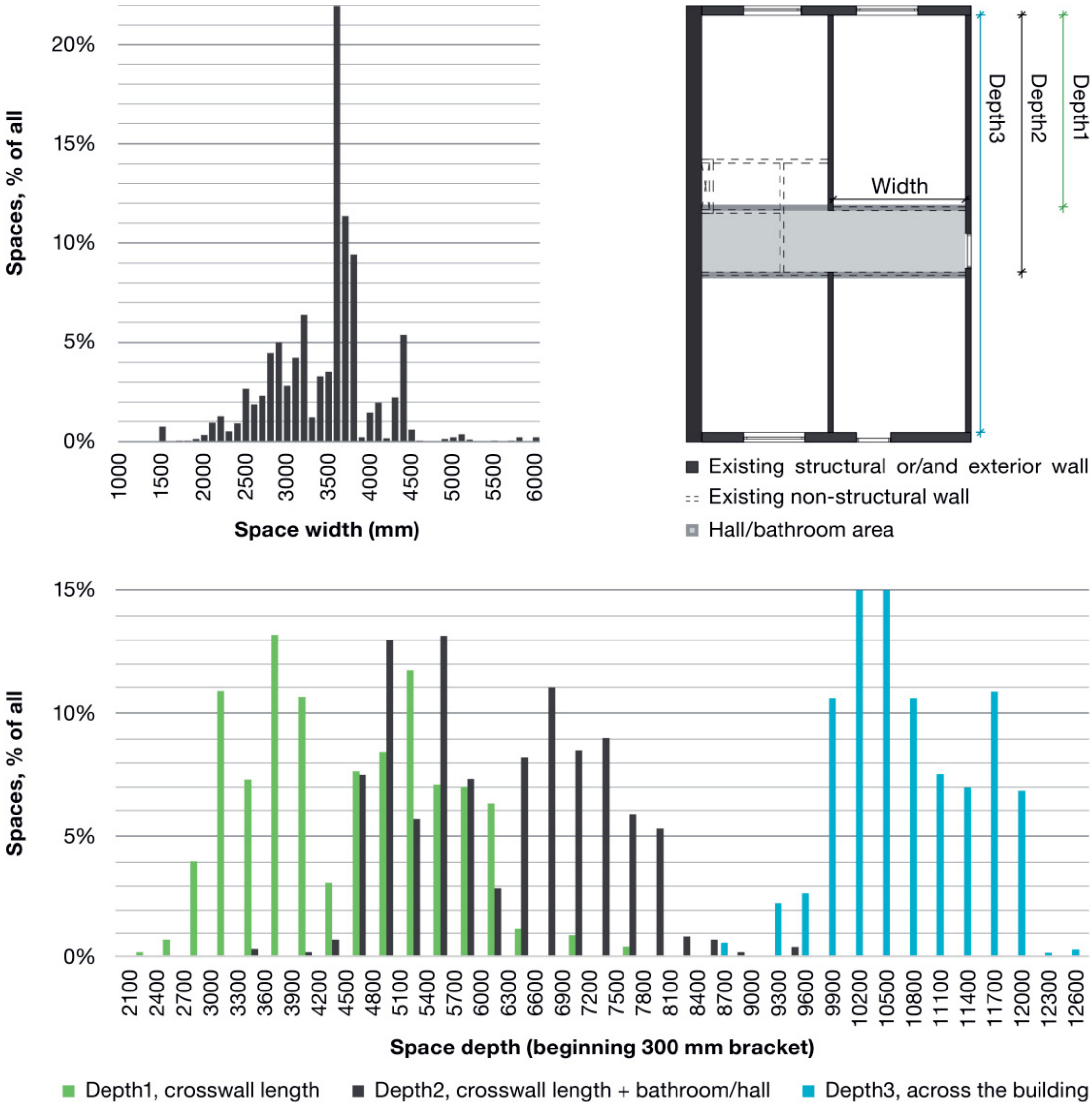


Figure 15. Dimensions of potential spaces in existing apartment buildings. The dimensions presented are based on the 2569 spaces on the 105 slab block floors used as a sample for article I.

Space width corresponds straightforwardly to the distance between structural crosswalls. Compared to the dimensions of habitable rooms presented in figure 14, ignoring non-structural crosswalls introduces some wider spaces in the >4200 mm range. Overall, however, the difference in width distribution is quite minor, as is to be expected considering the prevalence of structural crosswalls in the sample and stock (section 3.1.2).

For depth, three different figures are shown. Depth1 indicates the depth of spaces as defined by structural crosswalls starting from the façade. For most habitable rooms this is approximately equal to the original depth of the room—not for all, however, as illustrated by the top left room in figure 15. Depth2 extends the above distance with the middle area of the building, which typically contains the hall, bathroom, and/or walk-in closet. The depth used for the middle area (2000 mm) is the median depth of a bathroom in the primary research sample. Thus the total figure for each depth2 is an approximation meant to convey the general difference in comparison to depth1. Finally, depth3 covers two opposite habitable rooms and the middle area between them, i.e. the entire interior depth of the building frame. As can be seen, even within each method of measuring potential space depth (1–3) the distribution of depths is much more uniform than that of widths.

Looking at the combination of width and depth, for depth1 most common values are around 3600 x 3200 mm (or reversed) and 3600 x 5100 mm. Corresponding to this, floor area for a single depth1 potential space peaks at around 12 m^2 and 20 m^2. Extending this to depth2, the peaks would be at approximately 19 m^2 and 26 m^2. For depth3, areas between 36 m^2 and 43 m^2 could be expected using the most common width of 3600 mm and the depth range of 9900–12000 mm. All of these are of course rather coarse approximations, but they serve as an indication of the wide range of room dimensioning achievable within the original structural boundaries.

3.2. Apartment level suitability and adaptability for independent housing

In response to the first research question—'How suitable or adaptable are existing apartments for independent housing for older people?'—this section examines the suitability of existing apartments for independent housing for older people in either their original state or with varying degrees of modifications. First, the methodology used is described (section 3.2.1). Following this, the results are discussed first in terms of the layouts and general properties of existing apartments (3.2.2), from which the examination progresses to specific rooms and their associated functions (3.2.3), leading into a concluding summary (3.2.4).

3.2.1. Assessment methodology

The assessment of apartment level suitability and adaptability for independent housing built on the earlier examination of existing apartment buildings (**A** in figure 16, section 3.1) by first **characterizing the spatial properties required by independent housing for older people** (**B**) and then **comparing the fit between spaces available and required** (**C**). Characterizing the spatial requirements was based on a literature review. The comparison part consisted of research by design and a multi-case study. The suitability and adaptability process formed by the above parts is summarized in figure 16 and further discussed below that.

[a] Parts B and C are distinct stages of the research process. However, to more clearly present the needs and potential for adaptation, these are discussed together in sections 3.2.2 and 3.2.3.

Figure 16. The process of apartment suitability and adaptability assessment. For all parts of the process, 'available' refers to properties of the existing apartments, while 'required' refers to the needs of housing for older people. Part A has been covered in detail in section 3.1, but is presented here to more clearly convey the whole process. Research stages preceding the topic of the current main section are presented in gray.

In the first phase (**B1**), literature including design guidance, norms, and existing research was reviewed to identify the **properties of layouts required** for successful independent housing for older people. This included aspects such as apartment room count and spatial connectivity. Closely connected to this, in the second phase (**B2**) the focus was shifted to the **properties of individual spaces required.** In contrast to the above, these comprise e.g. the dimensioning and furnishing needs of specific rooms. It should be noted that neither phase aimed to construct a set of strict design solutions. Rather, the goal was to form a sufficient knowledge base for the following phases assessing the properties and potential of existing apartments.

The third phase (**C1**) began the comparison of fit between spaces available and required through the **assessment of apartment layout suitability and adaptability**. Here the recurring apartment types (**A1**) were examined to evaluate how well the typical layouts present in the existing building stock suit the needs of older people identified in phase **B1**. Due to the cost and amount of work involved in altering apartment boundaries, the focus was on possibilities available inside the existing apartments.

In the fourth phase (**C2**), **assessing function specific suitability and adaptability**, first the recurring apartment types (**A1** and **A2**) were evaluated in light of the requirements for independent housing for older people (**B1** and **B2**) to identify common, recurring accessibility issues. These are summarized in figure 17 (left) and table 4, and further discussed in section 3.2.3. Following this, a set of generalized accessibility improvement models (AIMs) addressing these issues was drafted by the author for the six most common apartment types. The AIMs were originally drafted as part of the author's master's thesis in architecture (Kaasalainen, 2015). Thus, the drafting process was guided by a professor of housing design and two additional subject matter expert instructors at Tampere University School of Architecture. Furthermore, the finalized thesis including the models was reviewed by ten senior staff members of the School of Architecture. In Hauberg's (2011, p. 51) definition for research by design, this would constitute the part where '[the research] is validated through peer review by panels of experts who collectively cover the range of disciplinary competencies addressed by the work'. The AIMs used the most typical dimensioning determined when forming the apartment types (section 3.1) and are thus based on theoretical archetypes formed from a large number of apartments instead of any specific single apartment. Through this typological approach, the method allows combining detailed examination with a high degree of generalizability. The applicability of the AIM for the most common apartment type (2–1A in figure 13, AIM presented in figure 17 (right) and table 5) was tested in article III. The other AIMs can be found in the aforementioned Finnish language master's thesis (Kaasalainen, 2015, pp. 177–252).

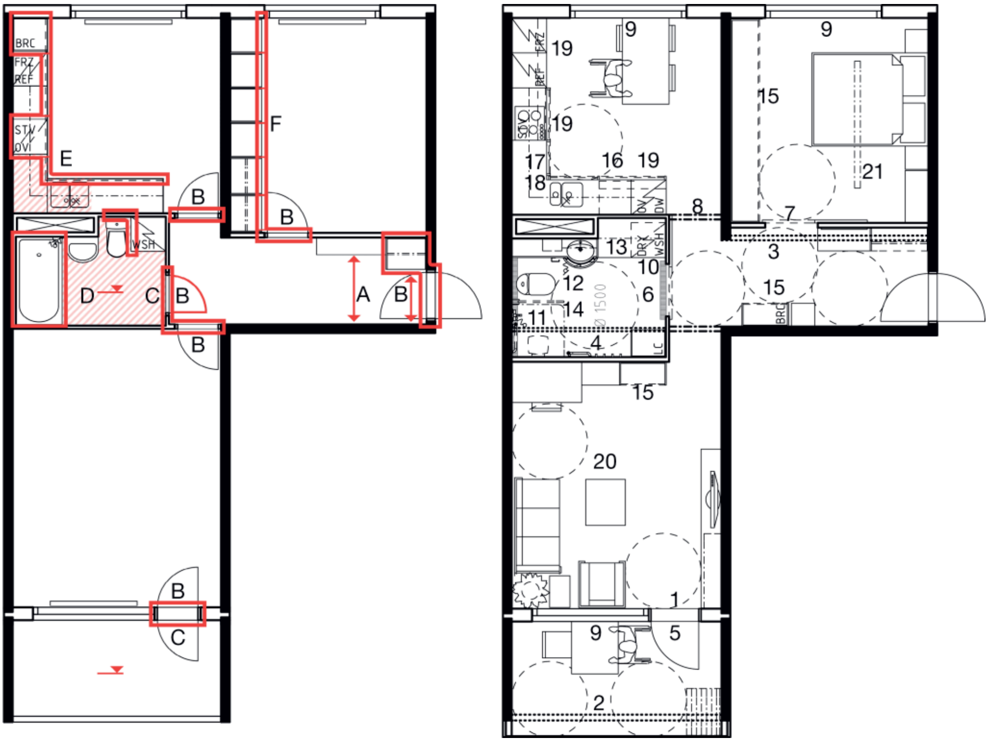


Figure 17. Recurring accessibility issues and the accessibility improvement model addressing them. The presented and tested model is for the most common two room apartment type in the studied building stock. Annotations are explained in tables 4 (accessibility issues) and 5 (accessibility improvement model). (Adapted from article III.)

Table 4. Description of recurring accessibility issues. IDs correspond to the annotations in figure 17. For the implications and risks of the identified issues see article III, table 2. (Adapted from article III.)

ID	Location or object	Issues	Sources
A	Hall	Narrowness, especially near the entrance when original fixtures are in place.	Sorri, 2006; Kaasalainen, 2015
B	Doors	Narrowness; opening angle < 180°; two leaves (entrance and balcony); high thresholds (especially balcony and bathroom).	Sorri, 2006;
C	Floor	Level difference between the bathroom and the balcony and the rest of the apartment.	Verma et al., 2012; Kaasalainen, 2015
D	Bathroom	Lack of space; high threshold to tub; slippery, difficult to clean materials.	Neuvonen, 2006
E	Kitchen	Low and shallow toe kicks, no knee space, deep and narrow cabinets and closet, no dishwasher; sink in the corner.	Sorri, 2006;
F	Bedroom	Deep and narrow closets with hinged doors .	Verma et al., 2012; Kaasalainen, 2015

Table 5. Apartment modifications included in the tested accessibility improvement model. IDs correspond to the annotations in figure 17. (Adapted from article III.)

ID	Modification	Purpose
1	Level difference removed between hall and bathroom as well as living room and balcony.	Ease of moving; reduced risk of falling; enabling use with a wheelchair.
2	Balcony extended or replaced with a larger one and equipped with glazing.	Enhanced usability.
3	Bedroom wall pulled back.	Increased spaciousness in the hall to enable wheelchair storage and easier moving.
4	Bathroom extended towards the living room.	Increasing spaciousness in the bathroom to enable use with a wheelchair or a walking aid and to ease assistance.
5	Old doors replaced with larger, single leaf doors with no thresholds.	Ease of use and moving.
6	Larger entrance to the bathroom with a sliding door and without a threshold.	Ease of use; enabling use with a wheelchair.
7	Sliding door to the bedroom.	Ease of use.
8	Kitchen and living room doors and their frames removed.	Easier moving.
9	Windows changed to ones with a lower sill.	Easier use of window mechanisms; increased visibility when seated.
10	Trench drains added.	Draining water from the floor when the threshold has been removed.
11	Bathtub replaced with an accessible shower.	Easier use; enabling use with a wheelchair.
12	Toilet seat and sink moved.	Easing assistance and the transfer between a wheelchair and the toilet seat.
13	Added a laundry closet and a washer/dryer combination with increased table space.	Ease of use.
14	Grab bars added where needed, structural requirements for future installations considered in relevant places.	Ease of use; reducing the risk of falling.
15	Closets replaced with shallower and wider models with sliding doors.	Ease of use.
16	Kitchen cabinets replaced with drawers.	Ease of use.
17	Lowered upper cabinets with ability to pull down if needed.	Ease of use.
18	Knee space and deeper/taller toe kicks added.	Enabling use with a wheelchair or when seated.
19	Dishwasher added; a stove/oven and a freezer/refrigerator replaced with separate appliances.	Ease of use; reduced risk of sustaining burns.
20	Furniture rearranged.	Easier moving and providing space for a wheelchair user.
21	Lift installed above the bed.	Easing transfer between the bed and a wheelchair.

The applicability of the accessibility improvement models, and through this the adaptability of the apartments, was tested by applying the AIM to a sample of nine existing apartments (see figure 18). The full AIM covers a wide variety of improvements including e.g. surface materials and (artificial) lighting, all of which have a significant effect on concrete accessibility. However, since these are largely independent from the shape of the spaces, and to focus on spatial characteristics and avoid the need for in-person visits, this test was restricted to properties observable from apartment floor plans. Furthermore, considering the age of the studied buildings it is unlikely that most surface materials, let alone fixtures, would have been original anymore. As described in sections 3.1.4 and 3.1.5, the design of individual spaces varies very little between the different apartment types, as does the basic central hall based layout. Thus the observations made using this single apartment type are also applicable to the vast majority of the rest of the apartments. Additionally, since dimensioning during the era was highly monotonous (sections 3.1.4 and 3.1.5), it is likely that many of the findings also apply outside the recognized recurring apartment types.

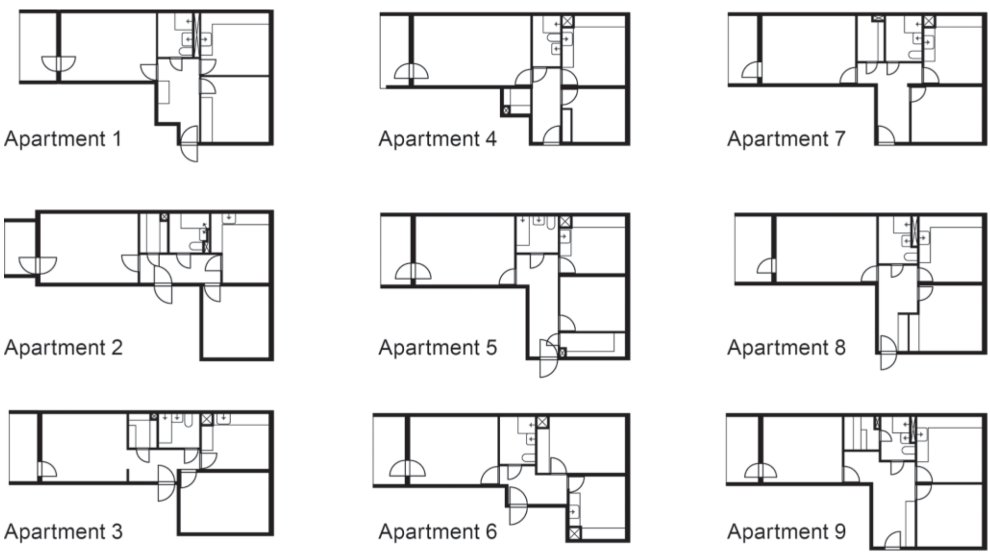


Figure 18. Accessibility improvement model test cases. (Adapted from article III.)

It must be noted that the test cases were a convenience sample in the sense that they were picked from the city of Tampere, where the authors had easy access to the construction supervision archives, and from neighborhoods known to have buildings of the studied type and year range. This was done to minimize unnecessary effort in searching for and gathering material. The cases were also picked as evenly across the year range of the apartment type defining sample (1968–1985) as was possible. As discussed in sections 3.1.2–3.1.5, the studied building stock is very spatially uniform regardless of specific age or location. Therefore, it is unlikely that the sampling process had any significant effect on the representativeness of the test sample compared to a random selection from the entire comparable Finnish stock.

3.2.2. Spatial structure

Studios and two room apartments comprise approximately two thirds of the studied stock (section 3.1.4, table 3). In terms of room count the majority of the apartments are thus suitably sized for most older people, who typically live alone or at most with a partner (section 1). While larger apartments obviously offer more customization options, they are also more costly and laborious to maintain, which may cause a need to downsize even if there are no other issues with the dwelling.

Although large apartments already constitute a minority of the studied stock, in some areas splitting them might still be well justified. Riihimäki et al. (2019, p. 19) point out that in declining municipalities, where population ageing is also strongest, the greatest proportion of vacancies is in apartments with three or more rooms. Two room apartments cover only a quarter of all vacancies and vacant studio apartments exist only here and there. Therefore there is great pressure on these municipalities to convert large apartments into multiple smaller ones, for which there is more demand. Although addressing the issue in depth is outside the scope of the current research, it is worth noting that the existing building floor layouts make altering apartment sizes spatially quite simple. Often the only difference between existing apartments of different sizes is the number of rooms attached to the central hall (see figure 13). Furthermore, the sizes of apartments typically do not affect the arrangement of spaces defined by structural walls on a given building floor much, if at all. This can be seen clearly by studying stairwells with different apartment combinations that are located in the same slab block. An example of such a case is presented in figure 19.

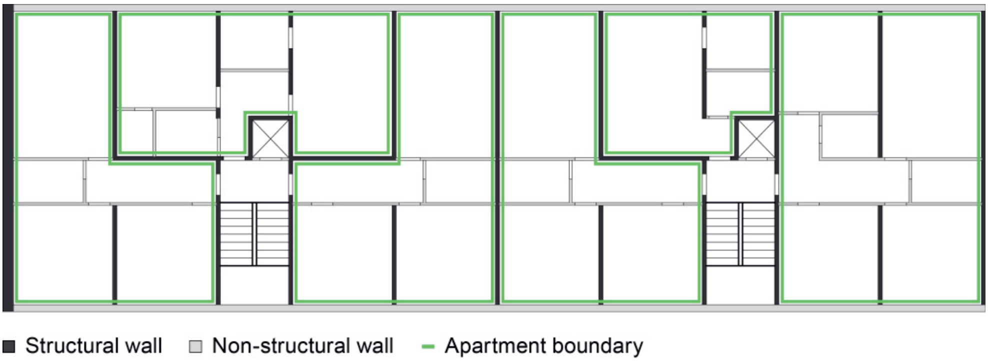


Figure 19. Structural layout and apartment boundaries in two adjacent stairwells of a typical slab block.

Therefore, when it comes to layout, changing which apartment a room belongs to is mostly a matter of closing a doorway and creating a new one. Even the otherwise often troublesome structural crosswalls can be of benefit here. Being structurally identical to those between existing apartments, they require less modifications to function as an apartment boundary than non-structural partition walls would. Exploring the potential of changing apartment boundaries, Huuhka and Saarimaa (2018) have conducted an extensive investigation of the typological possibilities available by merging and splitting apartments found in this building stock. Of course, in practice these layout considerations are only the beginning and many other issues such as electrical circuits also need to be taken into account.

As noted above, practically all apartments in the studied stock that are larger than a studio are formed by rooms arranged around a central hall. Aside from some kitchenettes and walk-in closets, the only—very rare—exceptions include bedrooms that are accessed through the kitchen or the living room. This creates a clear, easily comprehensible layout and minimizes the need to pass through habitable rooms to reach other ones. Therefore it is also simple to for example convert a living room to a bedroom, or to separate the original bedroom or living room for use by a caregiver. Then again, this layout means that going from one room to another requires a detour through the hall even if the rooms are directly adjacent. Although adding a doorway to the partition wall is possible, it is not entirely straightforward since this wall is typically structural (section 3.1.2).

3.2.3. Function specific suitability and adaptability

The suitability and adaptability of the spaces within an apartment for independent housing for older people are discussed here separately for each room type and associated function. Although relocating some functions might be useful or even required in some individual circumstances, maintaining the original spatial composition is likely to correspond best to a typical use case, needs, and resources. Therefore maintaining the original locations is considered the primary approach. The results of applying the accessibility improvement model (AIM, figure 17) to the nine test cases (figure 18) are summarized in table 6 and further discussed below that, together with observations on the usability of the spaces without adaptations. Furthermore, balconies are also briefly discussed despite them not being a space within an apartment in the same sense as the actual rooms, due to the potentially high wellbeing effect of having easy access outside (e.g. Mäntylä et al., 2011, p. 10; Mooney and Nicell, 1992, p. 29).

Table 6. Applicability of the accessibility improvement model in the tested cases. (Adapted from article III.)

	Living room	Bedroom	Kitchen	Hall	Bathroom
Apartment 1	■	■	■	▒	▒
Apartment 2	■	▒	■	▒	□
Apartment 3	■	□	–	□	▒
Apartment 4	■	–	■	▒	■
Apartment 5	■	□	–	■	▒
Apartment 6	■	■	▒	▒	■
Apartment 7	■	▒	▒	■	■
Apartment 8	■	■	■	■	■
Apartment 9	■	■	■	■	▒

■ Applicable without changes: the room in the test apartment is as large as or larger than in the AIM and of a suitable (similar) shape.

▒ Applicable with changes to layout: the AIM can be implemented by moving fixtures or furniture, which can still be placed accessibly.

□ Applicable with additional structural changes: the AIM can be implemented by conducting structural changes that are not proposed in the AIM but do not compromise the function of adjacent room(s).

– Not applicable: the AIM cannot be implemented without compromising the functionality of the current room or adjacent room(s), even with additional structural changes.

Living room

Unsurprisingly considering its typically relatively generous dimensioning and lack of any fixtures, the living room presented no issues when applying the AIM in any of the test cases. The target layout could be applied in all of them without changes even after expanding the bathroom as required by some of the cases. Correspondingly, as all the changes made concerned furnishing, the living room can be considered suitable as is without any spatial adaptations. To improve visual access outside and physical access to the balcony, however, changing the windows to ones with a lower sill and the balcony door to one that is wider, has a lower threshold, and only a single door leaf would often be beneficial as noted in table 5. Considering that many older residents are likely to spend most of their time in their apartment (HAPPI, 2009, p. 31; Horgas et al., 1998, p. 561), often due to going outside being difficult (section 1.1), such changes can have a significant quality of life impact.

A full survey of window dimensions in the existing apartments was not conducted. However, for the 73 distinct studio apartment layouts found in the sample, an approximate figure of 5 m² of window area per apartment was determined. In most cases, this consists of a large window for the main room and a much smaller one for the kitchenette. This large window is typically the same size as in other living rooms of the building, while bedrooms and kitchens have somewhat smaller ones. Considering that the current building regulation minimum for the window of a habitable room is 10% of the room's floor area (A1008/2017), existing spaces should receive ample daylight given suitable orientation.

Bedroom

For bedrooms, most of the difficulty in applying the AIM stemmed from the need to fit a two person bed. This was the case even with wheelchair accessible open space on only one side of the bed, in front of only some of the closets, as illustrated in figure 17. Conversely, all nine case apartments could easily accommodate a single person bed—even the one now marked 'not applicable'—with ample room to spare in front of the closets. Fitting two single beds would also be easier to accomplish than a single large one, assuming they would not have to be accessible from both sides and could thus be placed along the walls. In conclusion, however, based on these test cases and observing the dimensioning of rooms in the larger research sample of 320 buildings, it is evident that most of these apartments are unable to accessibly accommodate a two person bed in the room originally intended as the bedroom without changing the layout or boundaries of the room. Changing the boundaries of the room, on the other hand, is often infeasible without rendering the adjacent hall unusable.

Since existing living rooms are virtually always larger than bedrooms, in some cases it might well be justified to swap the locations of these two functions. Doing so would of course require accepting a smaller living room in exchange. For residents who spend much of their time in bed this change would also have the added benefit of the living room usually having originally been designed to be less secluded, thus facilitating a better connection to the surrounding world despite limited mobility.

Kitchen

The size of the kitchen as well as the location of its entrance are quite fixed in all of the typical apartment layouts, as the room is usually surrounded by structural or exterior walls and the bathroom (see figure 13). Correspondingly, the AIM tested was mostly applicable either with no or minor changes, or not at all. The main issue encountered was that a fully accessible kitchen requires a vast amount of furnishable wall space: after placing all the necessary appliances there was very little room left for counter space or drawers. On the other hand, a dining table for four people could be fit reasonably well in all of the kitchens, including the two where the AIM was otherwise not applicable due to the above issues. Furthermore, many adaptations such as replacing cabinets with drawers and adding grab bars do not depend on the amount of space available and can offer benefits even if compromises must be made otherwise.

Considering the results of the AIM application test in light of the typical dimensions observed for kitchens in the larger stock (section 3.1.5), it can be concluded that in most apartments kitchen adaptations will need to be somewhat tailored to individual needs. A fully accessible, comprehensively equipped design that still has a reasonable amount of storage space will often be infeasible so compromises will have to be made between e.g. having a separate cooktop and oven instead of a combination stove or having the refrigerator and freezer as separate appliances. These compromises will be even more unavoidable in the case of the kitchenettes common in studios and some two room apartments (e.g. 2–3A in figure 13), which are typically very tightly dimensioned. Many of them might ultimately require relocating the kitchen into the adjacent living room to form a layout more typical in modern Finnish small apartment construction. However, as previously noted by Verma et al. (2006, p. 7), highly functional results can be reached just by customization based on individual needs, even if the design does not technically adhere to all modern guidelines for new construction.

Hall

The hall, along with the bathroom, is a room that previous literature has pointed out as one of the most problematic spaces in the studied building stock, mainly due to insufficient space (Sorri, 2006; Verma et al., 2006). These issues of dimensioning were also clearly visible in the nine apartment sample used for testing the AIMs. Small bathrooms and halls were also very common in the larger research sample of apartments. Still, based on the current study these problems are not insurmountable: only one of the halls in the AIM applicability study required more changes than relocating the non-structural wall bordering the bedroom, and three of the halls could accommodate the proposed layout even without this relocation. With these varying degrees of changes required, all of the nine halls could accommodate the proposed layout.

Bathroom

With a median and average floor area of 4.3 m² and a total range of 3.8–4.8m², the bathrooms in the nine AIM test cases were on the spacious side compared to the typical floor areas (median 3.9 m², interquartile range 3.5–4.4 m²) observed in the larger research sample (section 3.1.5). This is presumably at least partially due to the full sample also containing studio apartments, which typically are somewhat more tightly dimensioned. Despite this spaciousness, all of the bathrooms had to be expanded to accommodate the fully wheelchair accessible layout prescribed in the AIM. Then again, in all of the tested apartments this expansion was feasible due to the spaciousness of the adjacent living room, even if in some cases this involved removing or at least downsizing a walk-in closet or sauna.

With regard to the dimensioning required, an important consideration is whether need for assistance is accounted for. When the AIM applicability test was conducted and the related article III was published, the Finnish building regulations required at least one bathroom of an apartment to fit a 1500 mm turning circle (Ympäristöministeriö, 2004). The regulations have since been changed so that in so called regular housing a turning circle of only 1300 mm is required in the bathroom, and the earlier 1500 mm is required only in assisted living or housing specifically aimed at people with mobility impairment (A241/2017, 2017). Correspondingly, some of the adaptation test cases might be able to fit a version of the AIM with the more compact bathroom dimensioning. This, however, would include an increased risk of needing to conduct further renovations later on to respond to changing needs and should thus be considered only if the more spacious alternative is infeasible to implement.

Although studios or the two room apartments with layouts derived from those (e.g. 1–1A and 2–3A in figure 13) were not tested, it appears highly likely that in those creating an accessible bathroom would require expanding the existing space into the adjacent kitchenette, and correspondingly relocating the kitchen elsewhere. As noted in the section on kitchens above, relocating the kitchen might be a necessity for accessibility anyway, so planning and implementing both adaptations together would be advisable. Finally, as with the kitchen, even if compromises have to be made regarding dimensioning, other adaptations can still be highly beneficial. For the bathroom specifically, replacing a bathtub with a shower is an adaptation often highlighted in literature, as are grab bars (section 1.3). Neither of these requires expanding the existing room boundaries, although grab bars might require wall reinforcement when attached to a non-structural wall.

Balcony

Most balconies in the studied stock are accessed from the living room and span the entire width of the room. Thus they are typically at least 3.6 meters wide. The depth of the balcony varies, starting from approximately 1.5 meters early in the studied era and increasingly extending thanks to new requirements set for publicly funded housing production (Neuvonen, 2006, p. 220). Although their width makes most balconies fairly spacious in square meters, the lack of depth poses a problem for actual accessible usability. As noted earlier, unwieldy doors and level differences are also a common occurrence. Furthermore, original railings are often fully opaque, reducing visibility outside especially when seated. Finally, the balconies originally rarely have glazing, making them less suited for use for much of the year without modifications. Many earlier studio apartments also do not have a balcony at all, since it was only in the year 1977 that balconies became the norm for all apartment production. Overall, refurbishing, extending, or outright replacing original balconies is something that should often be considered, especially when considering housing for older people, who may have significant difficulties in going further outside. This has been highlighted for future research.

3.2.4. Summary and further considerations

When tested with a sample of actual apartments, the accessibility improvement model drafted based on a theoretical representative apartment type proved applicable in most cases (6 out of 9). Unsurprisingly, especially considering the focus on spatial properties observable from floor plans, the most common issue in the studied apartments was lack of space. This was exacerbated by the strict partitioning of the apartments into separate rooms, most of which are largely surrounded by structural or exterior walls, which makes reallocating space between the different functions often difficult or even practically impossible. Notably, however, the rooms previously singled out as the most problematic, i.e. the hall and the bathroom (Sorri, 2006; Verma et al., 2006), proved to be the ones with most potential for resizing and thus accessibility improvements through more comprehensive renovation works. On the other hand, while the kitchen and the bedroom had little room for expansion, they are comparatively easy to make compromises in when taking personal needs into account by simply reorganizing furniture and fixtures.

Even though fully applying the generalized, completely accessible AIM unchanged often proved difficult, on a room by room basis the success rate was 42/45 (93.3%), leaving only three rooms where it was deemed not applicable at all. One of these was a small bedroom unable to accommodate a double bed accessibly. In such a case, swapping the locations of the living room and bedroom could offer a solution, as could opting for two separate single beds. In the remaining two, insufficient dimensioning in the kitchen might be possible to deal with by carefully tailoring the design to the needs of the resident and ensuring future customizability.

In conclusion, it appears that most of the apartments in the studied stock have the spatial potential to function as independent housing for older people. While this will often require some adaptations, even structural ones, there are very few cases where conducting these would be spatially infeasible. As many of the adaptations will have to be tailored to individual needs, however, careful attention must be paid to not hinder or prevent further customization that might be needed in the future. Any renovation conducted should strive to maximize not only immediate accessibility, but also future adaptability, acknowledging the fact that during its life span the apartment may end up housing very different kinds of residents (Verma, 2020, p. 45).

3.3. Characteristics of existing assisted living group homes

The characteristics of existing group homes are presented here from the perspective of their objective spatial properties and correspondingly the adaptability of existing apartment buildings. Therefore, issues such as overall layout, variety of functions present, and dimensional requirements are included, while for example contemplating the efficiency or homeliness of the existing units in detail is not. However, it is undeniable that the latter are closely related to the real functionality of any group home. Thus some remarks on how the adapted designs compare to recommendations found in literature are included in section 3.4 when discussing the successfulness of the adaptations. For those interested in more discussion on these matters, without the context of adaptation, they are explored in detail and utilizing the same sample of facilities in an earlier Finnish language publication by the current author and colleagues (Kaasalainen et al., 2018).

3.3.1. Assessment methodology

Similarly to characterizing the existing apartment building stock (section 3.1), characterizing existing assisted living group homes was primarily a relatively straightforward typological process. Following from this, it also required similar initial consideration of scope and goals to determine the type and amount of material that needed to be gathered. Furthermore, the processing of that material had to take into account sufficient intercompatibility of the two typologies—apartment buildings and assisted living group homes—so that spatial adaptability assessment could be reasonably conducted. Thus, as with the apartment buildings, these preparatory stages are included in the following description of assessment methodology, both in figure 20 and the text below.

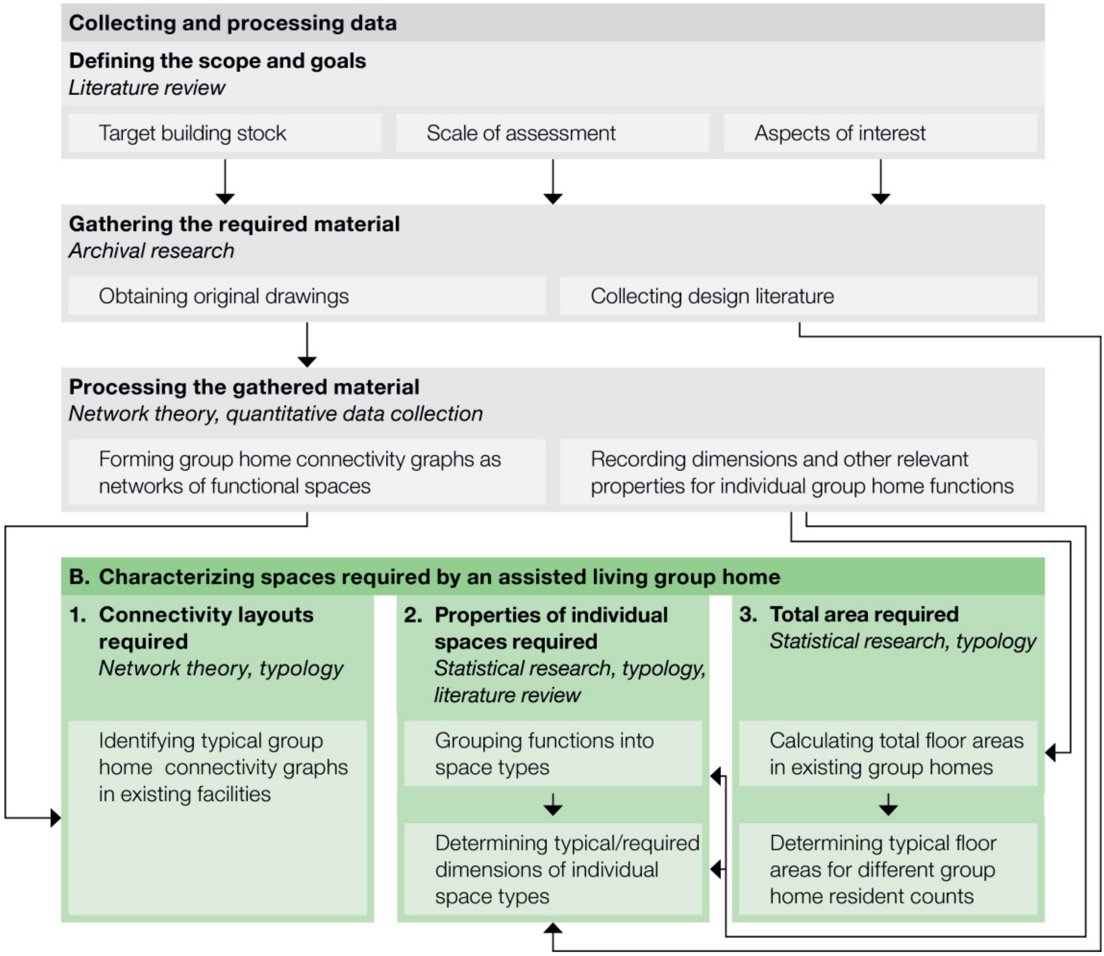


Figure 20. The process of determining the characteristics of existing assisted living group homes. The requirements of a group home unit in the later adaptability study (section 3.4) are based on these characteristics, hence 'required'. Research stages preceding the topic of the current main section are presented in gray.

For studying existing assisted living group homes for older people, **defining the scope and goals** comprised the following: the target building stock (multi-storey assisted living facilities in urban environments built or comprehensively renovated during or after the year 2000), the scale of assessment (individual and directly physically connected group homes), and the aspects of interest (spatial structure and function specific spatial properties). After this, **gathering the required material** from the construction supervision offices of the selected cities initiated the archival research stage of the data collection and processing phase. The material was obtained digitally in PDF format and consisted of a mixture of microfilm scans, rasterized CAD drawings, and vector format CAD drawings. In addition, literature on the design of group homes for older people was collected to cover aspects that might not be observable from the drawings.

Processing the gathered material began with organizing the drawings, assigning the group homes and the facilities containing them unique, hierarchical IDs, and scaling any drawings requiring it. This continued into forming connectivity graphs for all of the group home units in the sample (N=130, section 2.3.2). Unlike with the existing apartment buildings, for which connectivity graphs were formed based on existing physical spaces, here the concept of functional spaces (see section 2.2.2) was utilized. This way spaces with similar functionality and typically a shared access point to the main corridor were grouped into space types (for the specific groupings see table 8). This greatly simplified both the recording and analysis processes for the connectivity graphs while still retaining all relevant information for the purposes of the current study as well as the possibility of later increases in granularity.

Following the above, the floor area of each space type in each group home was recorded. Due to examining functional spaces, the total area for e.g. the laundry facilities of a unit was recorded as a single figure regardless of whether the function included separate washing and drying rooms. On the other hand, for some functions such as shared living room areas that could be be split into multiple non-adjacent spaces, it was also recorded how many separate spaces the function was divided into. This made it possible to better map the options available in the later adaptation study. Furthermore, since many functions are shared by multiple units either fully or partially (for details see section 3.3.3.2), a distinction within each space type was made between area used by only the single unit and area shared with one or more other units, including the number of the sharing units.

For **characterizing the spaces required by an assisted living group home**, the first phase (**B1** in figure 20) consisted of determining the **connectivity layouts required** by a single group home. For this, the group home connectivity graphs formed earlier were examined together with the original floor plans to identify recurring spatial layouts. As a result, a categorization was formed based on whether the main corridor formed a linear non-looping route, a looping route, or a hybrid of the above.

The second phase (**B2**) zoomed in on the **properties of individual spaces required** by the typical functions of a group home unit. Based on the figures recorded earlier, variation ranges and typical values for the dimensioning of each space type (i.e. functional space), and where relevant individual physical space, were determined. For the floor areas of the various space types, both total area and area per resident in the unit were considered. Finally, a complementary review of relevant literature was conducted to account for issues that would have to be considered in the adaptation study but might not be identified by simply observing the plans of the existing units.

The third phase (**B3**) consisted of determining the **total area required** by a single group home unit. Figures were calculated separately for each unit based on the space specific dimensions recorded earlier. Following this, variation ranges and typical dimensions for units of different size (in terms of resident count) were determined. In addition, a literature review of local design guidance and regulations was conducted to note any guidelines or binding requirements related to e.g. the dimensioning of a unit with a certain number of residents.

3.3.2. Scale, layouts, and connectivity

The number of residents per group home unit in the sample varied between 6 and 30, median being 14 and the interquartile range spanning 12 to 15. Thus, while there was a wide range of variation overall, in terms of the number of residents most of the units were quite similarly sized. These most common figures are around the upper end of the recommendations found in Finnish design guidance: 7 to 8 when residents have significant cognitive decline, according to Rakennustietosäätiö RTS (2013); 15 at most as a general guideline, according to ARA (2015). The number of apartments followed a very similar spread, ranging from 5 to 25 with a median of 13 and an interquartile range of 10 to 14.

As one would expect, the total floor area of a group home unit is highly dependent on the number of residents. Table 7 presents an overview of the relationship between resident count and floor area in three categories chosen based on the above local guidelines for unit sizes. Since many units share some of their common functions with one or more other units, figures are presented in two ways: as total floor area available for each unit to use, and as 'unit's own', where areas shared by multiple units are divided equally. In addition to the quite obvious fact of floor area increasing with resident count, it can also be seen that for floor area per resident there is an inverse relationship. The only exception in the presented figures is formed by the smallest units having less of their completely own space per resident. This is due to the smallest units in the sample on average sharing more of their common spaces with other units than was the case for the sample as a whole. For comparison, the floor area per resident recommended in Finnish design guidance is 45.0 m² or more, which excludes some technical and storage spaces (Rakennustietosäätiö RTS, 2013).

Table 7. Floor areas in the studied group homes with different numbers of residents. 'Total available' includes all common spaces directly connected to the unit in full, while for 'unit's own' any spaces shared with other units are divided evenly among those units.

Residents in the unit [a]	Absolute floor area		Floor area per resident		Sampled units
	Total available	Unit's own	Total available	Unit's own	
–8	337.5	250.9	50.2	36.9	14
9–15	650.4	596.1	48.7	44.6	94
16+	749.3	739.3	40.6	40.0	22

[a] The ranges for the presented resident counts are based on unit sizes recommended by Rakennustietosäätiö RTS (2013) and ARA (2015).

When examining the overall spatial layouts in the sample, practically all of the group homes were found to be arranged around some sort of a central corridor. A clear majority of 77.7% of the units use a linear, non-looping layout. Conversely, 11.5% of the units are nonlinear, meaning that the main corridor is circular. The rest, 10.8%, are a hybrid of the two consisting of a small loop from which extend linear wings, typically housing the apartments. Within these layouts, the location of specific functions varies. As a general trend, most shared spaces tend to be located in a single place within the unit. In approximately half of the units (49.2%) shared spaces are in a single cluster on both sides of the main corridor, while a quarter (25.4%) have them in a row with no apartments in between, and in the rest (25.4%) they are scattered around the unit. This tendency towards grouping shared spaces is presumably due to such a layout making it easier for the staff to monitor the residents. However, the variety present indicates that it is not strictly required for a group home to function. Regardless of the specific location of individual functions within the unit, or the linearity of the corridor layout, practically all main functions (section 3.3.3, table 8) in each studied unit were directly accessible from the main corridor. Overall, the variety of scales and layouts present in existing group home units suggests good potential for unit creation through repurposing other building types. Even though some arrangements are more common than others in existing units, there appears to be a multitude of feasible options.

3.3.3. Variety and dimensioning of functions

What distinguishes a group home from a group of independent apartments spatially is the presence and variety of shared functions and their location in relation to the apartments. Intensive sheltered housing group homes typically operate as closed units in the sense that their shared spaces are only accessible to the residents of the unit and possibly other adjacent units sharing some of them. Thus, while similar shared spaces are often present in the larger assisted living facility a group home is located in, the core functionality of a unit is largely independent from those. In the studied sample of facilities this was supported by the lack of any noticeable correlation between the variety of functions available inside group home units and outside them. As logically follows from the above, the vast majority of the group homes were found to contain the same general assortment of spaces (see table 8).

Table 8. Types of spaces found in the studied group homes. Grouping the specific functions into space types is based on their similarities in use and spatial requirements as well as often shared connection to the main corridor. (Article I.)

Type of space	% of group homes spaces found in	Specific functions included
Single resident apartment	100.0%	Single resident apartment and included bathroom.
Two resident apartment	62.2%	Two resident apartment and included bathroom.
Shared living room	100.0%	Lounges, hobby rooms, multi-purpose rooms.
Shared dining and kitchen	100.0%	Dining and kitchen areas, separate or partitioned from a lounge/living room area.
Shared washroom	77.7%	Washroom, attached changing room, toilet, sauna.
Laundry	95.4%	Laundry, drying room, utility room.
Staff areas	100.0%	Office, staff changing room, staff toilet.
Storage	100.0%	General and medicine storage, cleaning cupboard, rinsing room, waste collection.
Other	71.5%	Technical spaces, smoking room.

Within the full sample of group homes, apartments comprise a median of 50.5% of the units' floor area. The specific figure varies between 35.1% and 67.3%, but on the whole the distribution is fairly tight with the interquartile range spanning 45.3% to 54.5%. Group homes with more residents have on average more of their total area allocated to apartments and less to common areas than smaller units. Examined through the resident count ranges of –8, 9–15, and 16+ used in table 7, apartments cover on average 43.5%, 50.3%, and 55.1% of the units' total floor area respectively. More specific dimensioning of apartments as well as shared functions is discussed in the following subsections.

3.3.3.1. Apartments

Corresponding to the goal of replacing institutional settings with homelike housing (section 1.1), the group homes in the sample have mainly single resident studio apartments. Of the 1589 apartments in the sample, 89.4% are single resident, the rest being for two residents. While virtually all of the apartments designated single resident are studios, i.e. one main room and a bathroom, the less common two resident apartments have more variation. Namely, they either have one main room, being effectively larger versions of a typical single resident apartment, or two (see figure 21). Those with two mainly consist of a pair of equal main rooms accessed directly from a shared hall, with only a handful of cases requiring passing through one of the main rooms to reach the other. Regardless of the specific layout, all two resident apartments only have a single bathroom. Only one of the 130 group homes has any apartments without their own bathroom, thus being a clear exception.

Figure 21. Examples of group home apartment floor plans found in the studied sample. A single resident apartment and two resident apartments with one or two main rooms. (Adapted from Kaasalainen et al. (2018, p. 27).)

Most of the sampled group home apartments are very compact. The floor area for single resident apartments (N=1421) varies from 14.2 to 35.8 m² with a median of 23.6 m² and an interquartile range of 20.6–25.1 m². This includes the bathroom, which is typically approximately 4–5 m². The recommended minimum in Finnish design guidance is 25 m² (ARA, 2015; Rakennustietosäätiö RTS, 2013), which only 40% of the sampled apartments reached. This could be due to the guidance not being binding outside certain subsidy arrangements, or a result of renovations to older facilities, while comprehensive on the whole, still being affected by original structural elements. In a sample containing only facilities constructed during e.g. the last five years the share of larger apartments might be higher. In addition to general compactness, striving for efficiency through building foot print is clearly visible in the proportions of the apartments: most apartments are quite deep at six meters or more, and correspondingly fairly narrow (see leftmost example in figure 21 and dimensions in figure 22). This is confirmed by the average width/depth ratio for all rectangular single resident apartments (n=1177) being 0.75, meaning that on average an apartment is 0.75 times as wide as it is deep—or 1.33 times as deep as it is wide. Corresponding to the above areas and ratios, the most common combinations of width and depth are found around 3500 x 6100 mm, 4400 x 6000 mm, and 4000 x 6600 mm. When contemplating these dimensions it is important to keep in mind the inclusion of the bathroom. In the vast majority of cases this is located at the back of the apartment, near the entrance, as illustrated in figures 21 and 22. Thus, despite the designs being rather deep on the whole, the actual living areas in most are not very far from the façade.

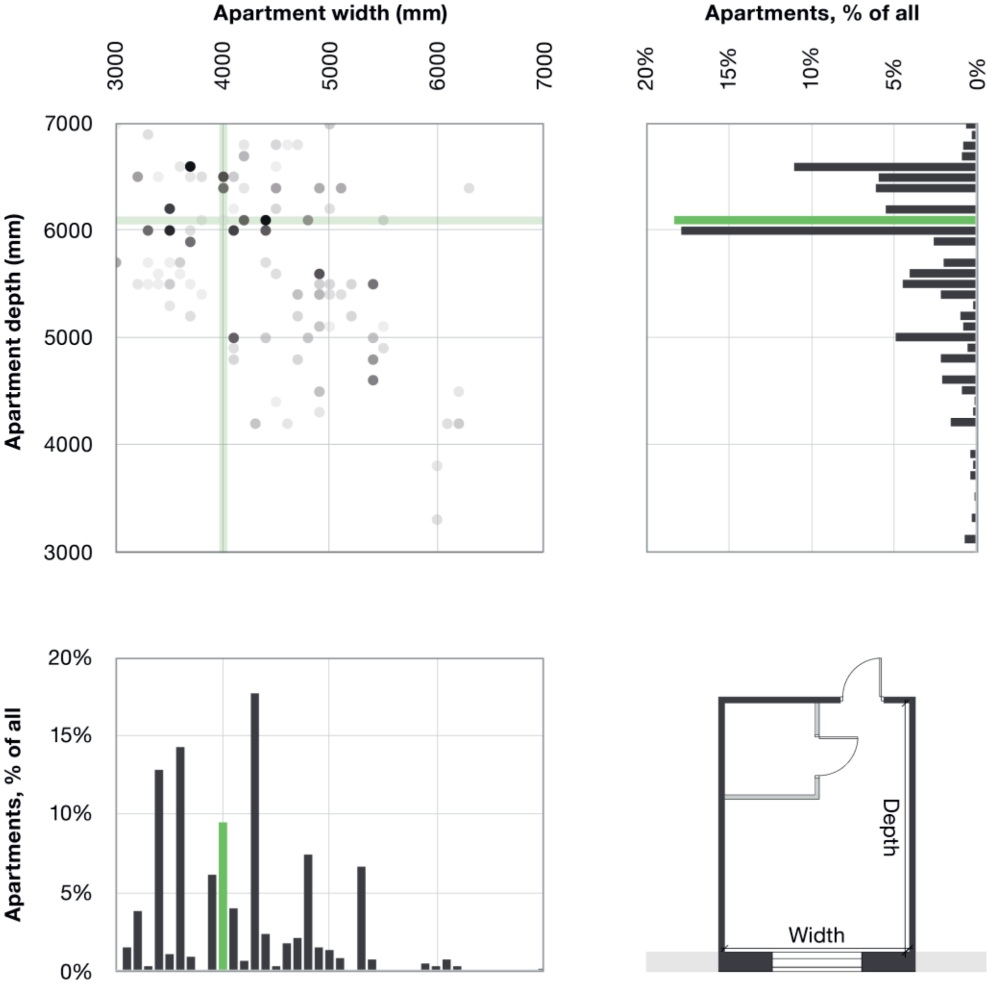


Figure 22. Dimensions and typical layout of single resident apartments in the studied group homes. Median dimensions are highlighted in green. Dimensions are from the furthest corners of the room, ignoring possible small niches in the walls (≤0.6m, common depth for closets), and rounded to the nearest 100 mm. Non-rectangular rooms were excluded, leaving a total of 1177 measured apartments. For rooms with multiple exterior walls, 'width' corresponds to the one with the most window area.

For two resident apartments (N=168) the full range of floor areas covers 18.7–46.0 m² with a median of 29.8 m² and an interquartile range of 26.5–35.8 m². Since these apartments are typically located side by side with the single resident apartments, their depths are mostly similar to those presented above. Correspondingly, they are of course usually wider than single resident apartments. Although widths and depths were not measured for two resident apartments, estimates can be made based on their floor areas and the depths recorded for single resident apartments. With the median single resident apartment depth of 6100 mm, the median width of a two resident apartment would be 4900 mm, and the interquartile range 4300–5900 mm.

Comparing the figures above with the ones for spaces in existing apartment buildings (section 3.1.5), it is already clear that in apartment building to group home repurposing most cases would require utilizing multiple existing spaces per apartment. This is the case even based on just the widths recorded and exacerbated by the space depths available in the apartment buildings. Very few apartment building rooms are six meters deep, meaning that most adapted designs will have to be wider than is typical for existing group homes to maintain comparable floor area.

3.3.3.2. Shared spaces

This section examines shared spaces present in the existing group home units, primarily from the perspective of floor area. Compared to apartments, these are much more varied in shape, making recording and meaningfully analyzing e.g. distances between parallel walls much more difficult. On the level of spatial connectivity, however, for some functions the examination does include the distribution of floor area within a space type, within a unit, or to an extent between multiple units. Of these considerations the last one is the most fundamental dimensioning difference to apartments, and vital to consider before making any observations about the typicality of designs. As established in section 3.3.2, some shared spaces inside group homes may also be used by residents of adjacent units. In fact, approximately half of the studied group homes (48.5%) share at least some of their spaces with one or more other units. As shown in table 9, aside from technical spaces and rare occurrences such as a smoking room ('other'), the function most commonly shared is storage, with nearly half of the units sharing at least some of their immediate storage spaces with others. On the other hand, very few units share all of their storage spaces. At the other extreme, very few units share their dining and kitchen areas, but those that do share them fully.

Table 9. Sharing of spaces between units among the studied group homes. (Partially adapted from Kaasalainen et al. (2018, p. 21), supplemented with unpublished data for article I.)

Type of space	Portion of units where spaces are shared with other units		Portion of area shared, in units where shared with others at all
	at least partially	fully	
Shared living room	21.5%	1.5%	54.9%
Shared dining and kitchen	4.6%	4.6%	100.0%
Shared washroom	38.1%	31.9%	90.3%
Laundry	24.6%	24.6%	100.0%
Staff areas	36.2%	20.0%	90.8%
Storage	46.9%	7.7%	73.6%
Other	51.6%	21.5%	76.1%

How much shared use by multiple units affects dimensioning varies between the different functions. For example, the shared washroom is affected very little, if at all, since there is typically only one of these and thus the increased use is not simultaneous. Conversely, shared living room and storage areas scale rather directly with the total number of users. For the purpose of defining the spatial needs of various group home functions for later adaptability study, this research uses the total amount of floor area available to the residents of a given unit. Within this approach, both the area required per resident and absolute area required are considered. This enables compatibility of data between different unit sizes through area per resident, while also preventing falling below practical minimum dimensioning, as might happen when determining dimensioning for small units by simply scaling the figures of the more numerous larger ones. The above means that the spatial requirements later used for single unit adaptation study will be somewhat overestimated, due to some areas originally being shared by multiple units and still being recorded in full for all of them. However, since storage is the only space type that is both shared often and to a high degree in terms of floor area, the effect is fairly minor. Storage is also the one that is by far the easiest to locate in any spaces left over after placing all the other functions of a unit, further mitigating the impact.

With all the different unit sizes and ways of sharing spaces between units there is much total variation in the dimensioning of most functions. The median values as well as interquartile and total ranges for the various recurring functions are presented in table 10 and further discussed following it. In general, the more residents a unit has, the less floor area each function aside from the apartments requires per resident. Most of the lower end of the per resident ranges is therefore covered by large units. Correspondingly, lowest figures for absolute area are from the smallest units. On the other hand, for some functions such as a washroom there is a practical lower limit in terms of absolute floor area, which raises the area per resident as well as the absolute area in small units. As a result, dimensioning in middle size units corresponds fairly closely to the median values.

Table 10. Distribution of shared space floor area in the studied group home units, total and per resident. 'Total available' indicates the area a unit has access to in full. 'Unit's own' indicates the area available when areas shared with other units have been divided equally among those units. Units lacking specific types of spaces entirely were excluded when calculating the corresponding figures. (Partially adapted from Kaasalainen et al. (2018, p. 24), supplemented with unpublished data for article I.)

Type of space	Area total (m²)			Area per resident (m²)			Share of total unit area
	Median	Interquartile range	Total range	Median	Interquartile range	Total range	
Shared living room [a]							
Total available	54.0	38.4–85.8	16.0–122.5	4.0	2.9–6.2	1.5–10.1	10.9%
Unit's own	51.3	38.0–69.0	16.0–122.5	4.0	2.9–5.3	1.5–10.1	9.5%
Shared dining and kitchen							
Total available	42.0	26.7–52.5	13.0–100.0	3.0	2.4–3.9	1.0–6.7	7.2%
Unit's own	41.2	26.5–52.1	13.0–100.0	2.9	2.3–3.8	1.0–6.7	7.2%
Shared washroom							
Total available	21.0	18.5–28.0	2.0–42.0	1.7	1.3–2.2	0.1–4.2	3.3%
Unit's own	15.4	9.5–24.5	2.0–42.0	1.1	0.9–1.8	0.1–4.2	2.8%
Laundry							
Total available	13.0	8.6–16.0	4.5–23.5	1.0	0.7–1.4	0.3–2.6	2.1%
Unit's own	9.6	6.0–16.0	3.0–23.5	0.8	0.5–1.1	0.3–2.6	1.9%
Staff areas [a]							
Total available	20.0	12.0–32.5	6.5–59.5	1.4	0.8–2.9	0.6–6.3	3.8%
Unit's own	13.0	10.0–22.2	6.0–41.0	1.2	0.8–1.6	0.5–3.2	2.7%
Storage [a]							
Total available	12.5	8.0–36.0	2.0–78.5	1.0	0.6–2.4	0.2–5.6	4.0%
Unit's own	10.3	4.3–31.7	1.0–46.0	0.8	0.5–2.3	0.1–3.3	2.8%
Other [a]							
Total available	3.0	1.4–5.5	0.5–11.0	0.2	0.2–0.4	0.1–1.0	0.4%
Unit's own	1.5	1.4–3.0	0.5–11.0	0.1	0.1–0.3	0.1–1.0	0.3%
Corridor							
Total available	107.8	80.0–152.5	44.0–241.0	8.2	6.5–11.5	4.0–20.1	18.6%
Unit's own	91.9	75.5–140.5	37.5–241.0	7.6	5.7–9.9	3.6–20.1	17.6%
Stairwell and elevator [a]							
Total available	34.5	28.0–43.5	15.0–69.5	2.5	1.9–4.1	0.1–7.7	6.0%
Unit's own	28.0	17.3–35.9	3.9–69.5	1.9	1.5–2.4	0.1–7.7	4.8%

[a] Functions included can be located in multiple spaces that are not connected to each other.

Shared living room

The total amount of shared living room area available varies greatly, regardless of whether one considers absolute floor area or floor area per resident. Following the trend noted above for shared functions in general, large units typically have less floor area per resident than small ones and vice versa, while the opposite is true for absolute floor area. Correspondingly, units that share some of their living room areas with other units have more of them in terms of total available floor area. Similarly to their floor area, the number of living room type spaces also tends to scale with the resident count of a unit. On average units with 8 or fewer residents have 1.1 living room areas, units with 9–15 residents have 1.8, and units with over 16 residents have 2.5. The overall most common number in the whole sample of units is two at 41.5%, followed by one (37.7%), three (18.5%), and four (2.3%).

Shared dining and kitchen

As with the shared living room, the dimensioning for the shared dining and kitchen area varies a lot from one unit to the next. It is also occasionally difficult to determine which of the two a certain area belongs to. In many of the studied group homes the shared dining and kitchen are located next to a common living room area, openly connected to it. In such cases the floor plans rarely indicate which parts of the area were allocated to which function, and table groups can obviously serve both uses. Therefore, when specific figures were not provided and the division could not be otherwise clearly distinguished, an estimation was made based on Finnish design guidance concerning the spatial needs of these functions (Rakennustietosäätiö RTS, 2013, 2008a, 2008b, 2006). Of a combined dining and living room area without a kitchen, a third was recorded as dining area and two thirds as living room area. With a kitchen, the area was split in half between the kitchen and dining area and the living room. In a majority of the studied units, the kitchen is homelike in design, i.e. smaller than a commercial kitchen and equipped with domestic appliances.

Shared washroom

The most common washroom configuration in the sample consists of a changing room, a shower room, a toilet, and a sauna. Even though the spaces recorded within this category also include toilets in the common areas of a unit (see table 8), when these exist they are nearly always a part of the shared washroom. Only one in four units (26.2%) has a shared toilet not accessed through the changing or shower room, and only half of these, i.e. one in eight overall, are accessibly dimensioned. On the other hand, a few units have no shared washroom but do have one or more shared toilets. Correspondingly, the total range of variation in floor area per unit for the space type is quite wide. However, most designs are rather similar in size due to the practical space requirements of the included functions, as evidenced by the interquartile range.

Laundry

Compared to all other shared functions, the area allocated to laundry appears to scale the least with the number of users. Neither the size of the unit containing the facilities nor the number of units using them has a notable effect—average areas for laundry facilities with one, two, or three units using them are all within a single square meter. Although it's been recommended that the laundry room is located next to the shared washroom (Lamminmäki et al., 2015), there is no recurring pattern for placement found in the studied group homes.

Staff areas

In the studied sample, the total floor area allocated to staff areas is heavily weighted towards the lower end of the observed total range, in both absolute floor area and floor area per resident. As with laundry facilities, the size of the unit appears to have no effect on the dimensioning of staff areas. All of the studied units have some sort of an office, but only 6.9% have any staff changing and washroom facilities aside from a toilet.

Storage

Similarly to staff areas, the dimensioning of storage areas in the studied group homes is strongly focused on the smaller end of the total range. Furthermore, examining floor area available per unit, i.e. with spaces shared with multiple units distributed evenly among them, the highest third of dimensioning is eliminated entirely. How the storage spaces are distributed within a unit also varies: some units have many small storage rooms, some fewer large ones, and some even have part of their storage as long closets along the main corridor. As with most shared functions, the amount of storage space correlates with the number of residents so that large units have more total floor area but less floor area per resident and vice versa for small units.

Other functions

In the vast majority of studied units, the functions grouped under the category 'other' consist of small closets for building services such as electrical systems. In a handful of cases, there is also a smoking room. In general, due to the minuscule amount of space required the effect of any spaces within this category is practically negligible for the layout and dimensioning of a unit.

Corridors, stairwells, and elevators

As with drawing the line between living rooms and dining and kitchen areas, separating corridors from adjoining functions often required some interpretation. Firstly, all areas directly marked as corridors or lobbies were recorded as presented. In the absence of such a marking—as was common with e.g. a living room spanning across a central corridor—the required area was allocated using the shortest practical route to all surrounding access points. The width used for this was either equal to the adjoining corridor, or 1800 mm in accordance with local design guidance (Rakennustietosäätiö RTS, 2006). The corresponding area was then subtracted from the overlapping other function, e.g. the living room. This allocation process was not applied to entrances leading only to the residents' apartments, as it was assumed that accessing these would be possible using the same routes that are required to move within the shared spaces. As discussed in section 3.3.2, most units use an efficient linear central corridor design. In addition, only few units have expansive lobbies, so most of this area consists of the minimum area required to access the different functions of a unit. Still, corridors—especially combined with stairwells and elevators—take up a significant share of the total floor area in the sampled units at approximately a quarter, regardless of whether sharing with other units is taken into consideration.

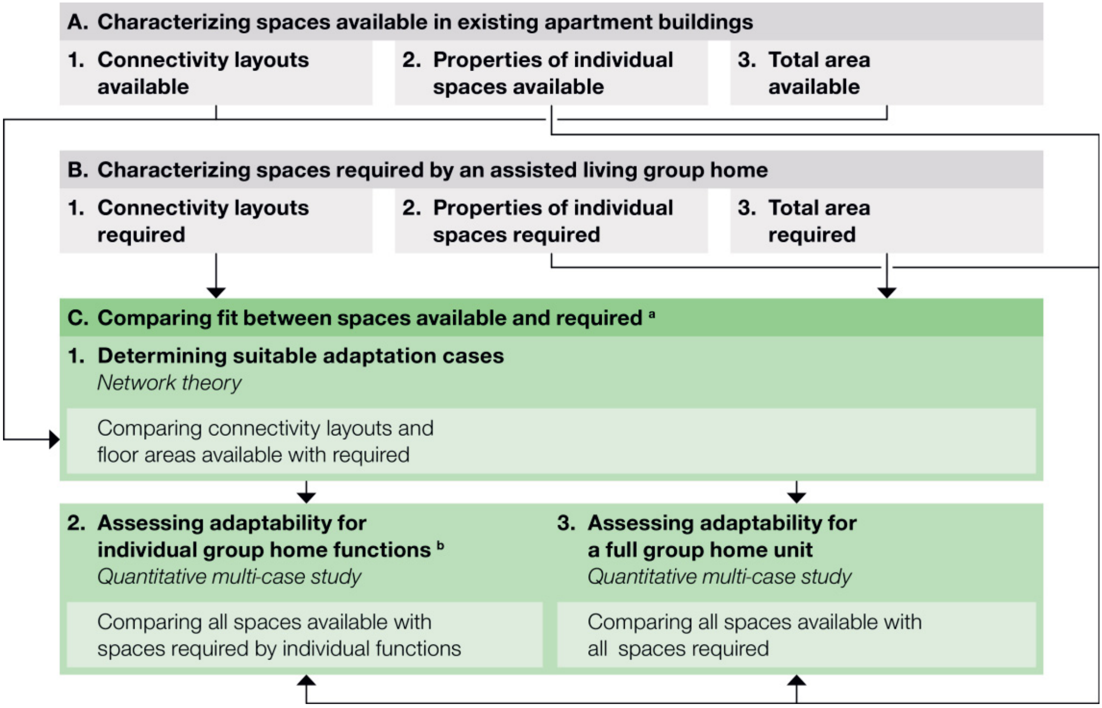
From the perspective of converting existing apartment building floors into group homes, the dimensioning present in existing units again presents a wide variety of options. Similarly to apartments, even a cursory comparison with typical apartment building dimensioning immediately indicates that functions such as the shared living room will require utilizing multiple existing spaces. On the other hand, there are also many functions, such as laundry and storage, that either take up very little space in total or can be easily distributed around the unit, providing much overall flexibility.

3.4. Building floor level adaptability into assisted living group homes

In response to the second research question—'How adaptable are existing apartment building floors into assisted living group homes?'—this section addresses the adaptability of existing apartment building floors into assisted living group homes for older people. First, the methodology used is described along with some intermediary results necessary to do so (section 3.4.1). This is followed by a description and discussion of the results (3.4.2–3.4.5), after which a concluding summary is presented (3.4.6). When considering the results, it should be noted that adaptability was assessed using existing slab blocks only. Although the reason for this was ultimately to keep the research process manageable, the restriction is also supported in many ways by the properties of the existing apartment building stock. Firstly, slab blocks form a clear majority of the buildings, comprising 71.6% of the primary research sample (N=320) and 75.7% of a comparison sample from ARA's Register of Real Estate (ARA, 2013) (N=1125). Secondly, most tower blocks could only accommodate the smallest of current group home unit sizes: the median gross internal floor area for a single floor of a tower block in the sample is 350 m², while even a seven resident unit takes up an average of 359 m². The overall average gross internal floor area for a group home in the sample is 633 m², corresponding to a 14 resident unit.

3.4.1. Assessment methodology

The assessment of apartment building floor adaptability into assisted living group homes built on the earlier sections, where typical properties were determined for existing apartment building floors (3.1) and group homes (3.3). Correspondingly, the methodology used is based on **comparing the fit between spaces available and required**, the former referring to the spatial reserve provided by existing apartment buildings and the latter to the spatial requirements of an assisted living group home. The comparison was conducted as a quantitative multi-case study. First, connectivity graphs and floor areas for both building types were compared to determine suitable adaptation cases. Next, the number and dimensions of spaces available on apartment building floors were numerically compared to those required by a group home. This was further divided into two parts: spaces available for each function individually, and spaces available for each function simultaneously. The adaptability assessment process is summarized in figure 23 and discussed in more detail below that.



[a] The resident counts of the adaptation cases determine the dimensioning used for shared functions.
[b] Assessing adaptability for individual functions is not a requirement for full group home unit adaptability assessment, but can be used to narrow down the designs to be tested.

Figure 23. The process of apartment building floor to assisted living group home adaptability assessment. For all parts of the process, 'available' refers to existing apartment building floors, while 'required' refers to the needs of a group home unit. Research stages preceding the topic of the current main section are presented in gray.

The first phase (**C1** in figure 23) of the adaptability assessment was **determining suitable adaptation cases** for repurposing. To this end, first the connectivity layouts of existing group homes were compared to the layouts present and possible on existing apartment building floors (in slab blocks, see sections 3.1.2–3.1.3), to ascertain sufficient compatibility and determine the changes required. Since earlier it was found that all residential floors of a given apartment building practically always have the same layout (section 3.1.3), only one floor per building was examined. As linear central corridor layouts comprise the vast majority of existing group homes (section 3.3.2), this basic layout was chosen for the adaptability study. Fitting this layout onto the existing apartment building floors required the addition of a central corridor, since originally none of them had one on the residential floors (section 3.1.3). After retrofitting the central corridor, both existing group homes and apartment building floors had practically identical connectivity graphs (see figure 24).

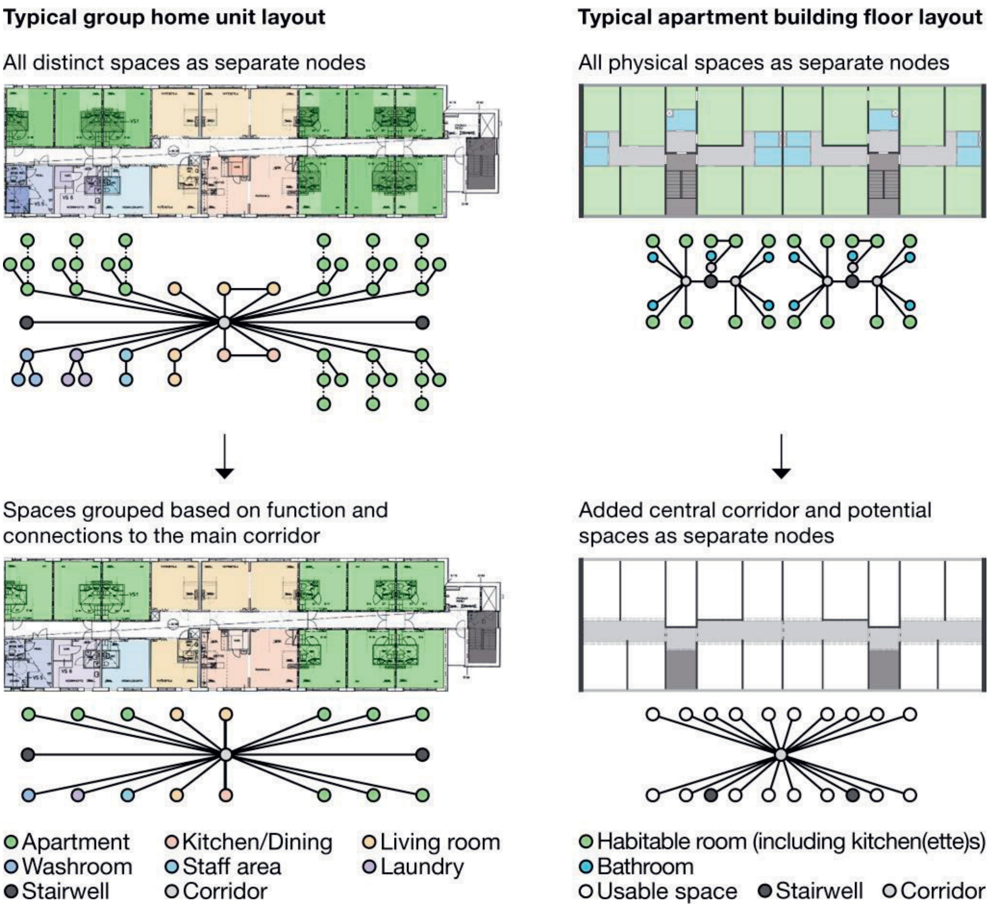


Figure 24. Spatial structures of a typical group home and apartment building in the research samples. Group home main functions with a single corridor access point have been consolidated into space groups. (Adapted from article I.)

Secondly, the typical floor areas of existing group home units with different numbers of residents were compared to the amount of total space available on existing apartment building floors to determine suitable group home sizes for adaptation. As noted in section 3.3.2, there is a wide range of variation in the dimensioning of existing group homes. Therefore, interquartile ranges (i.e. middle 50%) for existing group home floor areas were used here to avoid evaluating adaptability based on extreme examples. Comparing the floor areas available and required, two group home resident counts covering the highest number of apartment building floors in terms of floor area were chosen for use in the following phases.

After determining the adaptation test cases as described above, the second phase (**C2**) consisted of **assessing the adaptability of existing spaces for individual group home functions**. This step was conducted to determine which floors had at least some spaces suitable for each of the required group home functions and were thus sensible to include in the full group home unit adaptability study. The properties taken into consideration in the evaluation were floor area, minimum space width, and requiring a window. For floor area (m^2), two kinds of dimensioning based on existing group homes were studied: median and first quartile (i.e. the 25% point, midway between the median and the smallest recorded value). The floor area requirements for shared functions were determined as a median of existing group homes with a resident count similar (±1 resident) to the adaptation case units. For apartments, all apartments with the same number of residents were referenced, since their dimensioning is not tied to the size of the unit. Furthermore, comparing typical dimensions for existing physical spaces in apartment buildings (section 3.1.5) and the area requirements of group home functions (section 3.3.3), it was clear that many of the latter would require utilizing multiple existing spaces at once. Therefore, to also utilize potential spaces (section 3.1.6) merging adjacent or opposite spaces within the existing structural boundaries was included as an option, as was utilizing multiple non-connected spaces when possible.

Taking advantage of the repetitive spatial and structural nature of the target building stock (sections 3.1.2 and 3.1.3), two ways of allocating one or more spaces to a single function were determined. The first of these focuses on the different ways of forming an apartment utilizing one or more existing physical spaces, along one façade or at the end of a building. The process relies on categorizing existing spaces into ones that are at least 3000 mm wide, and thus can be used as the main residential room of an accessible apartment (Rakennustietosäätiö RTS, 2013), and ones that are narrower, and can thus only accommodate the bathroom and/or the entrance hall. Following from this categorization, a total of six different adaptation principles for forming apartments were defined for different combinations of adjacent existing spaces (figure 25). As shown, a single resident apartment can be formed either by fitting both the main room and the bathroom into a single existing space (A), or by placing them into adjacent spaces (B and C). Multiple adjacent single resident apartments can also be placed using principles D and E. In principle D, the hall as shown would then be replaced by the bathroom for one of the apartments. In principle E, the hall would either be separated from the apartments into shared space or split between the apartments. Two resident apartments can follow principles A–C directly, or a larger layout with two separate main rooms can be formed using principles D–F.

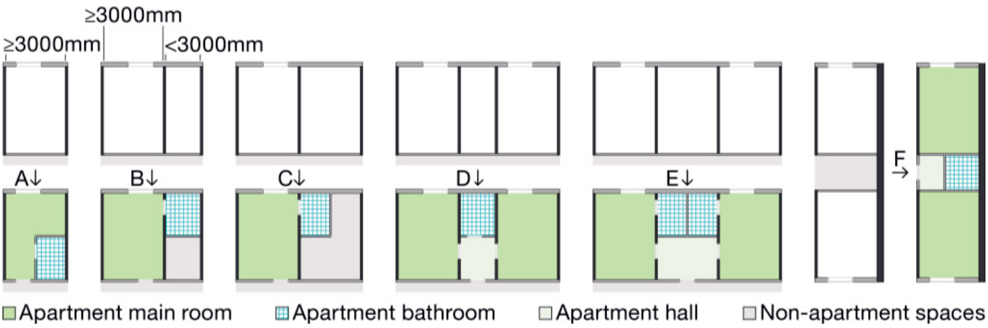


Figure 25. Adaptation principles for forming group home apartments utilizing existing spaces. (Adapted from article I.)

The second way of allocating spaces to a function pertains to the shared functions. For them, it is possible to use single spaces, merge spaces that are opposite one another across the central corridor, or use spaces that are not adjacent to each other at all. Combining the above options, a total of six different adaptation principles were determined (figure 26). Here the different privacy requirements of the various functions must also be considered. A shared living room for example can join and cross the central corridor openly, while a washroom cannot. Thus not all of the principles apply to all shared functions. Additionally, the shared functions also have their own minimum open space width requirements. They are presented in section 3.4.4.2 together with the discussion on what these requirements mean from the perspective of adaptability.

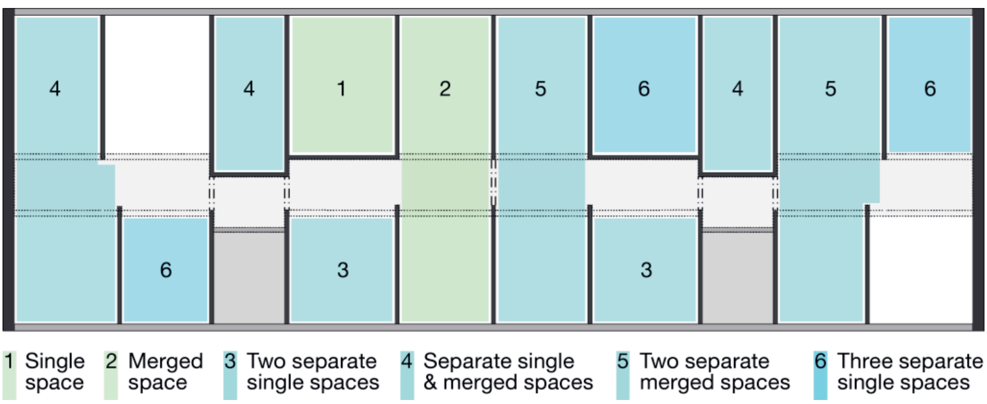


Figure 26. Adaptation principles for forming group home shared spaces utilizing existing spaces.

Utilizing the adaptation principles described above, each apartment building floor was examined to determine the spaces available for individual group home functions, both the apartments and the shared ones. For apartments, the number of floors that had any suitable spaces was recorded (see section 3.4.4.1), as well as the number of floors with enough of these spaces. For shared functions such a distinction was not required since there is categorically only one of each type in a unit even if they are located in separate spaces. Thus, only the number of floors with suitable spaces was recorded (see section 3.4.4.2).

The third and final phase (**C3**) consisted of **assessing building floor adaptability for a full group home unit**. As the previous phase showed that all floors had at least some suitable spaces for each individual group home function, each of the floors was also included here. Continuing from the previous phase, here the goal was to determine how often and how well all of the functions could be placed alongside one another without running out of suitable spaces. Since the results of the previous phase made it clear that median dimensioning would be mainly infeasible even for individual functions, only first quartile dimensioning was tested.

It would also have been an option to test various combinations of first quartile and median dimensioning, e.g. by using one for apartments and the other for shared functions, or even making decisions on a case by case basis for each function. However, to be practically feasible this would have required coding a relatively complex program to run tests for the massive number of possible combinations of dimensioning and adaptation principles. Moreover, testing only first quartile dimensioning is sufficient to assess whether adaptation is spatially feasible at all. Testing further combinations would merely provide more information on how often median dimensioning could be used instead. This, while interesting, was not required for the current assessment. Consequently, this study did not include such examination. During the testing process the various common functions were placed first, since their presence essentially defines a group home. This was followed by placing the apartments, the number of which only affects the efficiency of a design. Single resident apartments were prioritized, as they are most common in the existing facilities studied, and widely recommended as the primary solution for group homes (e.g. Cutler, 2007, 2008; Rakennustietosäätiö RTS, 2013; Zimmerman and Sloane, 2007). The adaptation principles used in this phase were the same ones that were earlier used to evaluate single function adaptability (figures 25 and 26). The function placement procedure, which was repeated for each of the cases, is presented in figure 27.

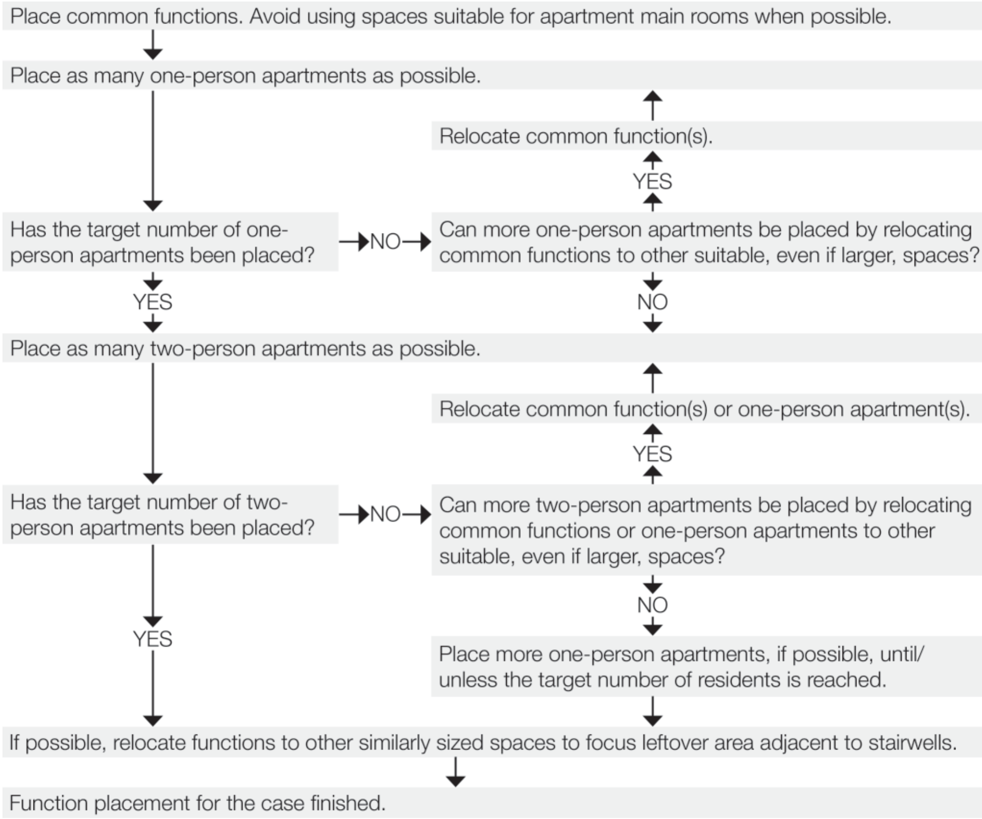


Figure 27. Function placement process in the full group home adaptability study. (Adapted from article I.)

After completing the above function placement procedure for each of the studied cases (N=100), the adapted designs could be quantitatively compared to the existing group home units. This included determining the amount of compromises required in the adaptation in terms of e.g. the number of apartments and overall space efficiency. Furthermore, the placement process itself provided insights into which functions were the most difficult to fit without compromising fitting others.

3.4.2. Spatial structure

Comparing the connectivity graphs for the two studied building types, retrofitting a central corridor was found to be a requirement to fitting a typical group home unit layout onto an existing apartment building floor. While this has a major impact on the original spatial structure, the actual construction works required are comparatively minor. When aligned with the original stair landings, the corridor is also typically aligned with existing apartments' entrance halls as well as bathrooms or walk-in closets and avoids most structural crosswalls and shear walls. The above is evidenced by not only the current adaptability study cases but also the typical apartment layouts in the studied building stock overall (see sections 3.1.2–3.1.4). With the central corridor all of the studied slab blocks were found to suit the typical linear group home layout well, allowing an identical general spatial structure (see figure 24). Considering the structural similarities and the similar dimensioning of individual physical spaces in slab and tower blocks (sections 3.1.2–3.1.5), it appears likely that small group homes could also be created in tower blocks. Due to their typically less oblong footprints, tower blocks might also be better able to accommodate non-linear layouts.

3.4.3. Overall dimensioning

As described in section 3.4.1, determining the group home unit sizes for the adaptation case study included comparing the typical floor areas of existing units to the amount of space available on the sampled apartment building floors. For all combinations of two different unit sizes, the interquartile ranges of 8 and 13 resident unit floor areas were found to cover the highest number of apartment building floors. Of the initial 105 slab blocks included in the group home adaptability study, a total of 100 (95.2%) had an amount of total floor area fit for a group home of 8 or 13 residents (see figure 28). Even the three buildings that exceeded the 13 resident unit interquartile range could of course accommodate the unit, bringing the potential total to 103 (98.1%), although realistically this would require utilizing only a part of the floor. Considering that the stairwells in slab blocks of the era are originally not connected on residential floors, this should not be an issue from a spatial perspective.

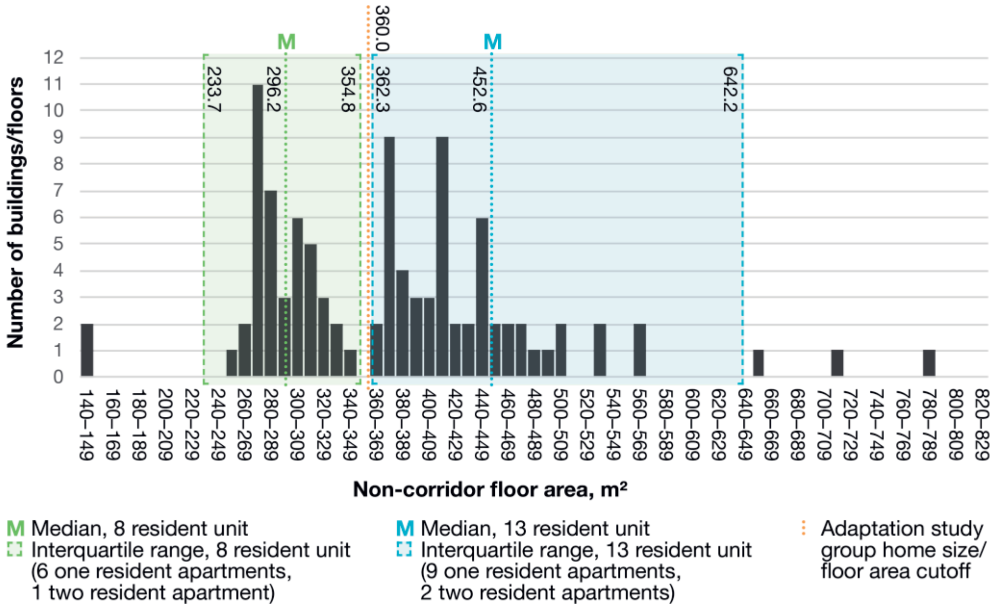


Figure 28. Non-corridor floor areas on apartment building floors (black bars) and interquartile ranges for 8 and 13 resident group homes (shaded areas). (Adapted from article I.)

The floor areas presented in figure 28 consist of only non-corridor area. With the corridor included, interquartile ranges for 8 and 13 resident group homes would be 313.1–475.4 m² and 440.8–781.3 m², adding up to a range of 313.1–781.3 m². For article IV, total floor area was recorded for 161 slab blocks and 65 tower blocks from the years 1968–1985. Of the 161 slab blocks, 80.7% are within the above range and 90.1% are either within or above it, allowing adaptation by potentially utilizing only part of a floor. Although tower blocks might not support the same layout, the same floor area comparison can be conducted for them too. Of the 65 tower blocks, 35.4% were within the 8–13 resident unit interquartile range, and 36.0% at least exceeded the lower bound—a considerably smaller figure in both categories than for tower blocks, as is to be expected. Finally, the first quartile area for a 14 resident group home, which was the median size in the entire studied sample of 130 units, is 641.5 m². This would fit in 27.2% of the slab blocks and 0.6% (i.e. one) of the tower blocks.

Based on the above, it can be concluded that most of the floors in the studied building stock meet the basic floor area requirements for accommodating a reasonably sized group home unit. At the same time, the ranges presented highlight quite clearly the wide range of variation in the dimensioning of existing group homes. Moreover, this variation clearly exists even among units with similar resident counts, as evidenced by the differences in first quartile values for 13 and 14 resident units (440.8 and 641.5 m² respectively). Thus there appears to be a multitude of realistic design options for adaptation in terms of overall unit scale and dimensioning.

3.4.4. Function specific adaptability

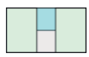
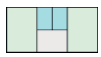
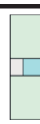
The adaptability of existing apartment building floors into assisted living group homes for older people is first discussed here from the perspective of individual functions. These are further categorized into apartments and shared spaces due to the different ways available for allocating space to them (section 3.4.1). For both types of spaces the specific spatial properties required are first presented, from which the assessment continues onto the availability of such spaces in the examined apartment buildings.

3.4.4.1. Apartments

As determined in section 3.3.3.1, for single resident apartments first quartile (Q1) dimensioning requires 20.6 m² of floor area and median dimensioning 23.6 m². This constitutes the floor area requirement when using adaptation principle A (single main room with the bathroom partitioned from the same space). The figures above include an accessible bathroom (4.5 m², and 0.5 m² for the partition wall), meaning that when using principles B and C (single main room with bathroom in separate space) the main room requires at least 15.6 m² (Q1) or 18.6 m² (median) of floor area. For a two resident apartment, placement using principle A requires 26.5 m² (Q1) or 29.8 m² (median). Principles B and C thus require 21.5 m² (Q1) or 24.8 m² (median) for the main room. The feasibility of layouts using principles D–F (multiple main rooms) depends only on whether the respective combination of wide and narrow existing spaces is present. Following from the requirement for a main room to be at least 3000 mm wide (section 3.4.1), floor area for the two main rooms is then always above median. With a median of 4.5 m and an interquartile range of 3.6–5.3 m, spaces in existing apartment buildings were on average much less deep than the apartments in the studied existing facilities (median 6.1 m, interquartile range 5.6–6.1 m). Thus the adapted layouts also ended up less deep than is typical in current new construction. This may have an effect on the furniture layouts possible, but should not make the apartments unusable, since similar plan shapes were also present in the existing facilities. A clear positive effect of this reduced depth is that being closer to the façade, the living areas will receive more daylight, providing potential benefits to resident wellbeing. At the same time, though, without proper shading overheating may increasingly become an issue for comfort and wellbeing, as even the deeper apartments in existing group homes are already at risk (Kaasalainen et al., 2020).

Table 11 shows the number of floors in the studied sample where apartments could be placed using the different adaptation principles (A–F) defined (section 3.4.1, figure 25). For each relevant combination of apartment type and adaptation principle, two figures are presented: the number of floors where at least some suitable spaces exist, and the number of floors that have enough of those spaces to fit all of the apartments for the studied group home size. Cells for unneeded or unsuitable combinations of apartment type and adaptation principle have been left blank. Similarly, Q1 dimensioning was not tested for apartments with two main rooms, since using principles D–F the area would always be above the median.

Table 11. Number of floors with spaces suitable for group home apartment creation using first quartile (Q1) and median (Mdn) dimensioning (N=100). The numbered adaptation principles are illustrated in figure 25. For 8 resident units the target number of one and two resident apartments was 6+1, for 13 resident units 9+2. (Adapted from article I.)

Adaptation principle used	 **Single room, bath included (A)**		 **Single room, separate bath (B or C)**		 **Two rooms, shared bath (D)** [a]	 **Two rooms, two baths (E)**	 **Two rooms, end of floor (F)**
Dimensioning used	**Q1**	**Mdn**	**Q1**	**Mdn**	**Mdn**	**Mdn**	**Mdn**
Single resident apartment [b]							
Any suitable spaces	46	23	100	86			
Enough suitable spaces	16	1	92	63			
Two resident apartment (single main room) [c]							
Any suitable spaces	15	8	42	20			
Enough suitable spaces	15	8	42	20			
Two resident apartment (two main rooms) [c]							
Any suitable spaces					66	100	87
Enough suitable spaces					66	100	85

[a] Principle D could also be used anywhere where principle E is feasible, resulting in more spacious dimensioning and the same number of suitable floors (100).
[b] For single resident apartments Q1≥ 20.6 m^2 and Mdn ≥ 23.6 m^2
[c] For two resident apartments Q1 ≥ 26.5 m^2 and Mdn ≥ 29.8 m^2

No single adaptation principle could be used alone to fit the required number of single resident apartments on all floors, although B and C together did come close at 92. However, a combination of principles A–C did allow placing the full target number of single resident apartments on all floors. Even this, though, was only possible using Q1 dimensioning, with median dimensioning only being possible on approximately two out of three floors.

The success rate for fitting any two resident apartments or the target number was identical for all principles except F. This is to be expected, since first of all 43 out of the 100 cases (i.e. the 8 resident cases) only required one such apartment. Furthermore, the remaining 57 cases targeted larger buildings, where the repetitive existing layouts meant that if one suitable combination of spaces was present another would likely be too. The difference when using principle F is due to some floors only having the suitable combination of spaces at one end of the floor. Unsurprisingly considering the floor area required, very few cases could accommodate a two resident apartment using principle A, in a single existing space, especially with median dimensioning. Having only a shared main room for the residents, the design could be considered inferior to the other options in any case, even when spatially feasible, due to the reduced ability to choose when to socialize (HAPPI, 2009, p. 28). Using principles B and C, the number increased more than twofold, but still remained quite low at 42 at most. With two main rooms, placing the required number of two resident apartments was possible on all of the studied floors.

As shown above, even when ignoring the shared spaces altogether, fitting a reasonable number of group home apartments onto an existing apartment building floor usually requires utilizing multiple different apartment layouts. The findings correspond to an earlier case study by Lyytikkä and Kukkonen (2006), which noted creating enough accessible apartments to be the main challenge in a repurposing project of this kind. However, the current results also indicate that the individual spaces available themselves do not prevent successful design of group home apartments.

3.4.4.2. Shared spaces

Unlike those of apartments, the floor area requirements of most shared spaces are highly dependent on the number of residents in the group home unit (section 3.3.3.2). Furthermore, these functions have different needs for privacy, minimum space width, and having a window outside. A summary of the spatial requirements considered here for shared spaces in the adaptability study is presented in table 12, for the specific unit sizes used.

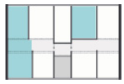
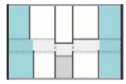
Table 12. Dimensions required by the group home shared functions for the tested unit sizes. Both first quartile (Q1) and median (Mdn) areas are based on units of similar resident count (±1) found in the sample. Other properties are based on requirements and recommendations in literature (A1008/2017; Kilpelä, 2019; Rakennustietosäätiö RTS, 2013). (Adapted from article I.)

Space type	Area (m²), 8-resident group home		Sampled group homes	Area (m²), 13-resident group home		Sampled group homes	Min. space width (mm)	Must have window	Can be open to other spaces
	Q1	Mdn		Q1	Mdn				
Shared living room	22.0	40.0	11	40.0	60.5	54	3000	Yes	Yes
Shared dining and kitchen	16.0	19.5	11	27.5	39.5	54	3000	Yes	Yes
Shared washroom	19.0	19.5	6	19.0	24.5	41	2000	No	No
Laundry	7.0	13.0	9	12.0	13.0	53	2000	No	No
Staff areas	11.9	22.0	11	13.8	25.5	54	2000	No [a]	No
Storage	5.1	6.0	11	9.0	12.5	54	–	No	No
Other	3.0	4.5	7	3.0	4.8	35	–	No	No

[a] Offices not for long-term working.

The number of floors where each individual shared function type could be placed using the different adaptation principles (1–6, see section 3.4.1, figure 26) are shown in table 13 and further discussed below that. As with apartments, results for both first quartile and median dimensioning are presented. Only those combinations of function and space allocation method that are usable in practice are shown in the table. Thus for example washrooms spanning across the central corridor are excluded for privacy reasons, and laundry rooms split into multiple spaces due to no such cases being present in the existing facilities. Furthermore, possible but unnecessary combinations are noted separately to more clearly present the least space consuming option. All of these further combinations would merely add spaces to an already successful principle, e.g. by using more than a single space for storage.

Table 13. Number of buildings with suitable spaces for group home shared functions with median (Mdn) and first quartile (Q1) dimensioning (N=100). (Adapted from article I.)

Space type	 **Single space (1)**		 **Merged space (2)**		 **Two separate single spaces (3)**		 **Separate single and merged space (4)**		 **Two separate merged spaces (5)**		 **Three separate single spaces (6)**	
	Q1	**Mdn**	**Q1**	**Mdn**	**Q1**	**Mdn**	**Q1**	**Mdn**	**Q1**	**Mdn**	**Q1**	**Mdn**
Shared living room	17	0	48	3	76	33	99	54	99	91	100	91
Shared dining and kitchen	48	32	99	48								
Shared washroom	86	46	98	98								
Laundry	100	100	*	*								
Staff areas	100	29	98	98	100	100	*	*	*	*	*	*
Storage	100	100	*	*	*	*	*	*	*	*	*	*
Other	100	100	*	*	*	*	*	*	*	*	*	*

* Possible but unnecessary.

Shared living room

The shared living room proved to be the most difficult to fit out of all the shared functions, especially in the 13 resident cases. As it requires such a large amount of space, no single existing space could fit a median sized living room (principle 1). Q1 dimensioning was possible on every sixth floor, all of which were 8 resident cases. Even merging spaces across the central corridor (principle 2) only enabled Q1 dimensioning in approximately half the cases and median dimensioning in a handful. On the other hand, as discussed in section 3.3.3.2, the living room can be and often is split into multiple smaller spaces. This is also recommended in literature on group home design (e.g. ARA, 2015; Hoglund and Ledewitz, 1999; Regnier, 2002) and can be seen to be in support of hominess often lacking in assisted living facilities (Gadakari et al., 2018, p. 23; Reed et al., 2007; Regnier and Denton, 2009). Furthermore, a number of separate living room areas can provide residents more choice regarding privacy than the simple dichotomy of their own apartment and a single common space. This in turn supports the highly valued ability to choose when to socialize (HAPPI, 2009, p. 28), even in a group setting. Utilizing the corresponding adaptation principles 3–6 enabled placing a Q1 sized living room in all of the cases, and a median sized one in most. Since large spaces in the existing apartment buildings very rarely have a structural wall on the corridor side, it is usually possible to have the shared living room areas open to the main corridor, promoting visual accessibility within the unit (PRP Architects, 2015; Rakennustietosäätiö RTS, 2013).

Shared dining and kitchen

The shared dining and kitchen area required utilizing merged spaces (principle 2) in most cases, although nearly half of the floors could accommodate Q1 dimensioning even in a single space (principle 1), and every third even median dimensioning. While neither principle 1 nor 2 was feasible on all floors, at least one of the two could be used on each. Theoretically it would also be possible to place the kitchen and dining area in separate rooms, providing more options for adaptation. This might also reduce the number of interruptions during dining caused by the room spanning across the central corridor, thus being beneficial especially in units with residents suffering from dementia (Day et al., 2000). For such placement to be practical in use, however, the spaces used would have to be right next to each other and possible to connect by creating a large opening in the dividing wall. While this is not impossible, significant structural challenges may arise—much more so than adding a regularly sized doorway as would be done when creating apartments using principles B–E (section 3.4.1, figure 25).

Shared washroom

The shared washroom could be placed in a single existing space (principle 1) on five out of six floors using Q1 dimensioning, and on nearly half even using median dimensioning. Utilizing merged spaces (principle 2) enabled placement on almost all floors, including the ones where single space placement was not possible. Here it is important to note that the merged spaces had to be located at the end of a building to avoid thoroughfare. This was possible at one or both ends in 98 cases, as shown in table 13, and at both ends in 82 cases. Similarly to the shared living room as well as the dining and kitchen areas, utilizing separate but adjacent spaces could also be feasible. Since the washroom facilities typically consist of a changing room, a shower room, a sauna, and a toilet (section 3.3.3.2), although not always in separate rooms each, existing partition walls would be less likely to cause problems. Furthermore, compared to the connection between a kitchen and a dining area, a much smaller doorway would suffice between e.g. a changing room and a shower room.

Laundry

The laundry room for both group home sizes was small enough to fit in available single spaces (principle 1) on each of the studied floors, with both Q1 and median dimensioning. Here it is worth noting that when creating a single group home in an apartment building without any of the utility spaces typically present in the rest of the facility, some extra space might be called for to accommodate e.g. more or larger washing machines than would otherwise be required. Seeing how effortlessly all existing floors could accommodate even a median sized laundry room, this seems unlikely to be problematic in any adaptation.

Staff areas

Staff areas, like the shared living room, can be spread around the unit as multiple separate spaces. Correspondingly, all cases could accommodate median sized staff areas when divided into two separate spaces (principle 3). Even a single merged space (principle 2) was possible on nearly all floors, though again with the restriction of no thoroughfare requiring placement at the end of the building. As with the laundry room, the presence of a larger assisted living facility is a consideration with the dimensioning of staff areas. Very few of the existing group homes had a staff changing and shower room within the unit (section 3.3.3.2), indicating that these are mostly located centrally for the entire facility. Therefore, allowing some more space for them when only repurposing a single floor would be justified. Again, though, this would be unlikely to pose a problem considering the minor amount of floor area required.

Storage

The typical amount of storage space was possible to fit in a single existing space (principle 1) on all 100 floors even using median dimensioning. In practice it is likely that distributing them in a less centralized manner would be useful, as was usually the case in the existing units. This would also be a propitious way of utilizing areas left over by other functions, e.g. when placing apartments using adaptation principles B and C (section 3.4.1, figure 25). Once again, lack of additional storage spaces in the larger facility when only repurposing a single floor is also something to consider, likely adding to the total floor area required but being trivial to accommodate.

Other functions

All other functions, i.e. mainly closets for building services and electrical systems, could be placed in any of the existing spaces on any of the apartment building floors. Like storage, these spaces can also be used to take advantage of leftover spaces that do not suit any of the other functions.

3.4.5. Full group home adaptability

When studying the various group home functions independent of each other, all 100 of the apartment building cases could accommodate the target number of single and two resident apartments as well as each of the shared functions. Therefore all of them were also potential candidates for a full group home adaptation. However, after the individual function placement studies it was apparent that only Q1 dimensioning was worth testing further. Very few floors would accommodate any reasonable full group home configuration using median dimensioning, at least using the chosen ways of space allocation. As noted in section 3.4.1, for the full group home adaptability study placing all of the shared functions was prioritized, and compromises were made in the number of apartments as required. With all of the shared functions accounted for, most apartment building floors could no longer accommodate the target number of apartments. Correspondingly, most could not accommodate the target number of residents. There were, however, some cases where even though no two resident apartments could be placed, the difference could be made up for by placing more single resident apartments. Table 14 presents the number and share of cases where the whole target number of residents could be fit, for both 8 and 13 resident cases separately and as a whole. In addition, the number and share of cases that could accommodate at least a number of residents one, two, or three fewer than the target is presented. On average, cases aiming for 8 residents could fit 6, and cases aiming for 13 residents could fit 8.

Table 14. Actual number of residents fit in full group home adaptation cases in relation to target number.

Number of residents fit, of target	8 resident target (n=43)		13 resident target (n=57)		All cases (N=100)	
	Number of cases	% of cases	Number of cases	% of cases	Number of cases	% of cases
All	4	9.3%	4	9.3%	8	8.0%
All–1	10	23.3%	6	14.0%	16	16.0%
All–2	27	62.8%	10	23.3%	37	37.0%
All–3	38	88.4%	12	27.9%	50	50.0%

In terms of apartments, of the 43 cases targeting 8 residents, 25 (58.1%) fit all single resident apartments and 37(86.0%) fit all but one. Of the 57 cases targeting 13 residents, 16 (28.1%) could fit all single resident apartments and 27 (47.4%) could fit all but one. Two resident apartments were much more difficult to fit, as was to be expected considering their greater spatial needs and the prioritization of single resident apartments (section 3.4.1, figure 27). Only ten cases total could fit the target number, six of which were in 8 resident cases and four in 13 resident cases.

Figure 29 shows an example of a case targeting 13 residents (i.e. nine single resident apartments and two two resident apartments), along with the starting situation. Here a total of nine apartments could be fit, all single resident. As can be seen, despite the case not reaching the target number of residents, some spaces were still left unused. This was due to more efficient arrangements not being available, i.e. there was no way of placing more apartments or replacing the presented ones with two resident versions while still keeping all common functions. Overall, these results concerning the difficulty of fitting accessible apartments are in line with earlier case study results on the topic (Lyytikkä and Kukkonen, 2006).

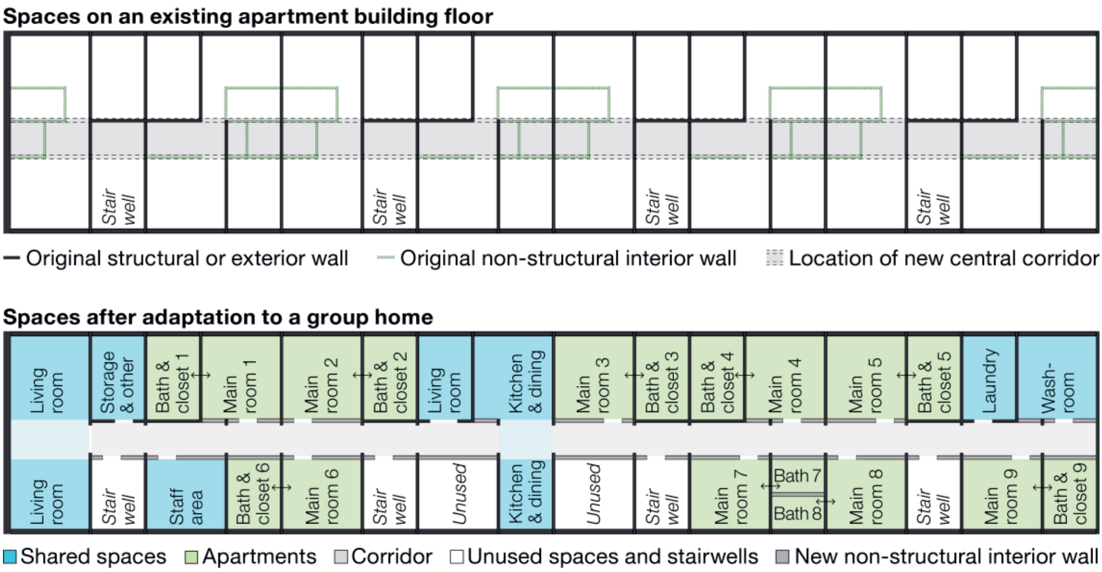


Figure 29. Example floor plan of a full group home adaptation. (Adapted from article I.)

As the results above imply, most of the group home designs created through adaptation ended up quite loosely dimensioned compared to existing units. Comparing group homes of equal resident count—using the actual number of residents fit, not the target number—the designs created in this study used on average 128.5% of the non-corridor floor area used by existing units. Furthermore, the adaptation designs used on average 84.8% of the total floor area available on the apartment building floors. Thus, if this leftover area were used for more shared or utility spaces (as it is not suitable for further apartments), the area used by the adaptations would reach on average 151.8% that of the existing units. As noted in the previous section (3.4.4.2), this might often be justified by the need for additional storage space and staff areas due to not having an accompanying larger assisted living facility present. On the other hand, since the adaptation designs are already comparatively spacious, the additional room for these functions might be available even within the spaces already allocated. As an alternative to expanding the unit, some of the leftover, unallocated spaces could still be used for non-group home functions. 91.4% of the leftover spaces were adjacent to a stairwell—either directly or through each other—and could thus remain independent from the group home. These spaces might be used by the residents of the rest of the building, or they could even house commercial functions possibly also serving the group home residents.

From the perspective of non-corridor floor area per resident, the adaptation cases range between 31.6–66.8 m² with an interquartile range of 41.4–49.3 m² and a median of 45.4 m². Although skewing higher, this is mostly within the variation found among the existing units, which range between 19.5–52.2 m² with an interquartile range of 31.0–39.5 m² and a median of 36.0 m². As noted in section 3.3.2, current Finnish design guidance recommends at least 45 m² per resident, which includes corridors but excludes some storage and technical spaces (Rakennustietosäätiö, 2013). Based on the studied existing group homes this would correspond to approximately 37 m² of non-corridor floor area, or 81.5% of the median value for the adaptation designs. Thus the dimensioning for the adaptation designs also ended up more spacious than the current Finnish minimum recommendations. Correspondingly, in terms of overall dimensioning they fulfill the recommendations better than most of the existing units studied.

3.4.6. Summary and further considerations

The results of this study indicate most existing apartment building floors to be spatially suitable candidates for conversion into assisted living group homes. Due to the restrictions imposed by the original structural frame, however, less efficient overall dimensioning will have to be accepted for the adapted designs than is typical in current new construction. Most notably, few apartment building floors can accommodate the numbers of apartments most often found in the existing units, which were firmly in the upper end of Finnish recommendations. Those that do fit such numbers will also require more floor area to do so than a building constructed for the purpose to begin with. However, the fact that many of the existing units failed to reach current recommendations for floor area per resident—for individual apartments and in general—and that much of the adaptation need could well be in areas and buildings with high vacancies (section 1.4), should make such added spaciousness easier to accept. Furthermore, literature commonly recommends keeping group home resident counts low, especially when the residents have severe cognitive issues (e.g. ARA, 2015; Daatland et al., 2015; Day et al., 2000, pp. 406–407; Netten, 1989; Rakennustietosäätiö RTS, 2013; Regnier, 2002, p. 137; Socialstyrelsen, 2010).

While the research presented here provides a picture of the overall potential for group home conversion in the apartment building stock, certain further considerations should be kept in mind when contemplating applicability of the results to concrete adaptation projects. Firstly, the dimensioning used for the various group home functions in this study was based on existing units, most of which are part of a larger assisted living facility. Therefore they usually also have at least some storage and staff areas available outside the unit. If the adaptation is carried out on the level of a single group home, or even multiple ones, without the other commonly accompanying parts of such a facility, these will obviously be missing. Therefore, allocating more space for certain functions within the unit created by adaptation might be required. To improve the usability of an adapted group home layout, it might also often be better to choose an arrangement that is not optimally efficient in terms of floor area used. For example, in the example shown in figure 29 locating the main shared living room at the very end of the floor is not necessarily the most favorable option. As the adapted designs tended to end up with significantly looser dimensioning than existing group homes, most actual implementations should have plenty of room for such adjustments.

Secondly, some of the spaciousness in the adapted group home designs resulted from the methodology used. Aside from some of the apartment adaptation principles, storage spaces, and 'other' functions, all functions were allocated existing physical or potential spaces in full even if the actual amount of floor area required was lower. In practice, utilizing the full depth of these spaces would not always be necessary, freeing up space along the central corridor. This space could then be incorporated into adjoining open plan functions or used for e.g. more storage. Furthermore, allocating adjacent spaces along a façade to a single function was only allowed for apartments, and certain shared functions such as living rooms which do not require a direct, open connection between those spaces. In a concrete adaptation project, adjacent spaces might often be merged even if doing so required structural reinforcement, if this enabled e.g. adding another apartment to the group home. This means that many actual adaptations could likely be more efficient than the theoretical ones formed in this study—at least with some structural changes, but often even without any. Moreover, narrow spaces problematic for adaptation mainly appeared next to wider spaces inside the same existing apartment. Therefore, buildings from the end of the studied era and the 1980s would likely be more suitable candidates for adaptation due to them having fewer structural internal walls (section 3.1.2).

Outside the actual group home, as with independent apartments, access to the unit must also be considered. As noted in section 3.1.3, very few buildings originally have an elevator. Even in the buildings that do have an elevator, its dimensioning is likely to be insufficient. Thus most group home adaptations on upper floors will require adding an elevator. To reach sufficient dimensioning this is likely to require significant changes to the existing stairwell and potentially placing either the elevator or a new set of stairs outside the original building envelope (for design options for this see Kaasalainen, 2015, pp. 66–85; Rakennustietosäätiö RTS, 2019).

Related to the above, an important topic is the provision of safe and safely accessible exterior spaces for the residents. While not examined in depth in the current study, this is highlighted as an area for future research. Existing work has shown access outside, both visual and physical, to be an important aspect of well-being for assisted living residents (e.g. Day et al., 2000; Rappe and Topo, 2007; Regnier, 2002, p. 54). In most of the existing facilities examined in the current work, the group homes were located on upper floors. Correspondingly, independent outside access for the residents usually meant access to a balcony, typically a shared one. When adapting an existing apartment building, similar results could be reached by merging and refurbishing existing adjacent balconies or—preferably, considering the typical dimensioning observed and the prevalence of structural sidewalls—constructing entirely new ones. Very few apartments in the existing group homes had their own balconies. In any concrete repurposing project, many existing spaces will have an adjacent balcony, which should be taken into account in the design when locating apartments and other functions.

Finally, the current work focuses on the design of group homes as self contained units, and on independent apartments for older people as their separate topic. Even for the sake of efficient service provision, however, it is likely that both would often be located in the same building. While this might not majorly impact the internal design of either housing type, such an arrangement would likely raise questions related to the placement of the shared functions often included in a larger assisted living facility, as occasionally noted in the preceding sections. Furthermore, any regular outside access to these shared functions would have to be taken into consideration. While detailed examination of the topic is outside the current scope, figure 30 illustrates some options for locating the various functions of such a facility in a repurposing project. The actual implementation would of course depend on e.g. the expected physical and cognitive condition of the residents, the functions present, and any outside use included. For example, the third option would clearly be the most favorable for outside use of the shared spaces, while the second and fourth options would allow group home residents independent access to the yard.

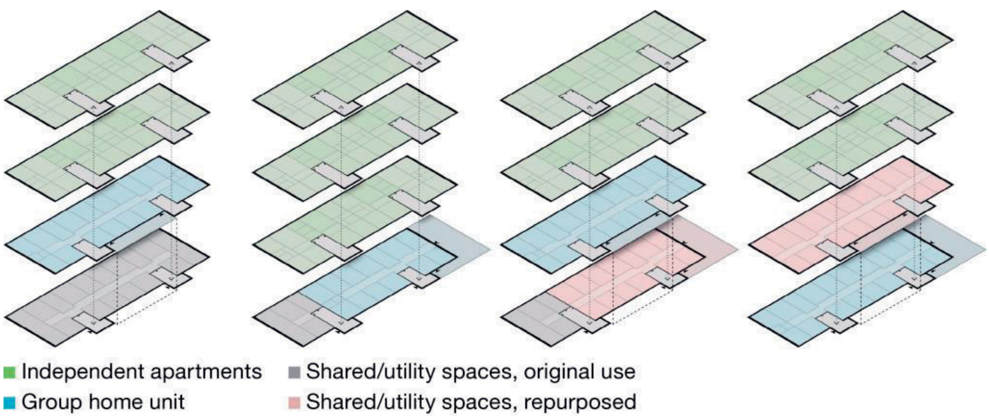


Figure 30. Schematic full building adaptation examples.

4. IMPLICATIONS AND LIMITATIONS

4.1. Theoretical implications of the research

4.1.1. Building stock and building adaptation research

For building stock research in general, the main methodological contribution of the dissertation lies in its specific typological approach and the accompanying overarching perspective. Typological study of buildings itself has been conducted by many previous authors, and even some typological adaptability assessment methods have been proposed. Complementing this existing body of work, the current research provides a thus far missing perspective spanning all the way from the considerations preceding forming the typology to actual practical examples of applying the typology. This not only establishes a framework (even if not a readymade toolkit) for the particular kind of examination conducted, but also exemplifies the potential such an approach holds for bridging the gap between academic enquiry and concrete design. In repetitive building stocks, such as that formed by Finnish post-war mass housing, even a small number of spatial archetypes can be representative of a vast number of actual cases. Thus, in both research and design—or research by design—a relatively high degree of detail can be combined with wide generalizability. As an added benefit, to a degree the broader perspective provided by such a typology also applies to existing case studies that have focused on smaller samples (in this case e.g. Pärnänen et al., 1994; Sorri, 2006). This has the potential to retroactively increase the utility of previous work by enabling further assessing the generalizability and correspondingly the meaning of their results. Moreover, consistently formatted and case-connected data behind the typology may be usable for entirely different research focuses. As Kohler et al. (2009, p. 450) highlight, such data can reduce the need for input data collection in further work and most importantly be used to connect different focuses, facilitating summarizing conclusions not immediately available through any singular piece of work.

For building adaptation research, as for architectural practice, the spatial typology of individual apartments formed in the current work shows the potential for the creation of mass-tailored renovation and adaptation plans and concepts. In repetitive stocks, once the recurring layouts and dimensions are confirmed, these can reach a much higher level of detail than would be possible based on individual case examples. Although such plans were here tested only in Finnish post-war apartment buildings, the basic methodology is highly likely to be directly applicable to other similarly repetitive building stocks, which exist in many other countries (sections 1 and 4.4). Considering that the layouts in Finnish mass housing production were never officially standardized (section 3.1.4, article II), the approach might even be more useful elsewhere (for examples see section 4.4). Furthermore, the specific case of accessibility improvements to facilitate independent ageing at home tested in article III is but one adaptation option for which mass-tailored designs could be utilized.

At the scale of individual buildings, it is notable that the spatial typology of apartments can be supplemented with information on common building floor level apartment combinations. Although not included in the scope of the current research, this potential approach was identified in article II and has already been successfully utilized by Huuhka and Saarimaa (2018), who explored the possibilities for size modification offered by combining the apartment types initially presented in article II. Broadening the scale further, forming connected higher level typologies based on recognized recurring apartment types could be used to study adaptation potentials in larger parts of the stock at the level of e.g. a neighborhood or a district. When the transformation options provided by typical combinations of likewise typical apartment layouts are known, existing and possible housing supply can be compared to local needs.

Similarly to the apartment types, the results of the building floor adaptability study (section 3.4, article I) can be used to estimate the repurposing potential in comparable parts of the building stock. Furthermore, the methodology employed is again not tied to the Finnish context and can also be applied to other suitably repetitive stocks. Likewise, different original and target uses can be substituted, as long as both the old and the new functions have a similar general spatial structure in terms of layout (existing or potential) and dimensioning.

Independent of any specific apartment or building layouts, the concepts of functional, physical, and potential spaces utilized in the current research proved useful for forming distinct but interlinked typologies. Combined with information on the spatial adaptation possibilities offered by the studied buildings, they provided a simple yet thorough way of assessing the options available in renovations of different comprehensiveness. For example, changes within existing physical spaces typically correspond to relatively minor changes, as was mainly the case with the assessment of apartment level adaptability (section 3.2). On the other hand, determining spatial requirements in terms of functional spaces and spaces available in terms of potential spaces suits a comprehensive renovation project, where boundaries are set primarily by the structural building frame, as was the case in the group home adaptability study (section 3.4). Ultimately, all of the above tie in to the principle of interlinked typologies endorsed by Kohler et al. (2009, p. 450), where different collections of information and their accompanying categorization systems are constructed in a way that supports utilizing them together.

As a general note on the methodology in the current work, research by design as employed in the building adaptability assessments (sections 3.2 and 3.4) proved to combine well with the typological approach to building stock characterization (sections 3.1 and 3.3). For individual apartments the detailed design process informed by literature and expert review enabled comprehensive examination. At the same time, utilizing statistically formed archetypes for this supported the applicability of the findings, and the designs as such, to the larger stock. For assisted living group homes, on the other hand, the more parametric approach allowed for a vastly increased number of cases, although at a lower level of detail, while retaining the generalizability benefits of the typological connection.

4.1.2. Research on ageing at home

As discussed in the introduction, the role of home modifications and building adaptation in supporting successful ageing at home is widely acknowledged, in both research and policy. More specifically still, the importance of utilizing the ageing mass housing stock for this purpose has been repeatedly pointed out (e.g. Pettersson et al., 2017; Slaug et al., 2020; Verma, 2019). At the same time, a lack of research has been noted on how the required renovations to facilitate said utilization could and should be conducted (Pettersson et al., 2017, p. 9; Smith et al., 2008, p. 302). The current research has worked towards filling this gap from the perspectives of two distinct types of housing for older people: independent and assisted living.

Firstly, a tested methodology for generalized, mass customizable accessibility improvement models (AIMs) was provided (section 3.2.1). As concluded in article III, the AIMs could be extended with complementary partial plans for e.g. individual rooms to further improve their applicability. Cost estimates could also be incorporated to facilitate the creation of product type adaptation packages. Furthermore, while the presented apartment type models already cover a significant part of Finnish dwellings, the same concept could also be extended to other parts of the housing stock as well as similarly repetitive stocks elsewhere (for examples see section 4.4). For example, Slaug et al. (2020, p. 15) have already noted that the typological classification introduced here (section 3.1, article II), and further utilized through the concept of mass customizable AIMs (3.2, article III), could be instrumental for research on the Swedish housing stock.

Secondly, to address the rising need in housing for not only accessibility but also care (section 1.1), a methodology was also formed, tested, and presented for studying the adaptability of existing apartment building stock into assisted living group homes (3.4.1). While the results obtained pertain primarily to the Finnish context, as noted in the previous section the methodology is again applicable to comparable repetitive building stocks anywhere, of which there are many (section 4.4). Thus a contribution was made towards further research on building repurposing as a response to housing ageing populations, where existing work was found to be sparse at best (section 1.3).

4.2. Practical implications of the research

The practical implications of the research are primarily related to supporting informed, fact based decision making in utilizing the existing apartment building stock. While previous work has pointed out the paramount importance of evidence based policy in the development of building stocks, the lack of such evidence actually being available has also been noted (Kohler et al., 2009, p. 453). The current research contributes towards closing this gap by providing information on the potential of the existing Finnish apartment buildings to respond to the needs of the ageing population. Furthermore, the typological information base and methodology developed support assessing the building stock's ability to respond to other important existing and upcoming needs. These include a variety of topics such as the diversification of household compositions (Gerson and Torres, 2015) and unconventional ways of working such as increased working from home (Felstead and Henseke, 2017). Overall, the information provided enables decision making that better acknowledges not only what the existing stock is, but also what it could be. This applies to all levels where housing related decisions are made, from national policy to individual homeowners.

The results of the current research indicate that from a spatial perspective refurbishing and repurposing existing apartment buildings is a viable alternative to new construction for housing the ageing Finnish population (sections 3.2 and 3.4). This finding applies to both independent housing for older people and assisted living group homes. Furthermore, the findings and assessment methods presented provide concrete ways for mapping local potentials for renovation and can act as a starting point for subsequent action at various levels. Considering the current renovation need of the housing stock (sections 1 and 1.2–1.3), the wellbeing effects of remaining active and in a familiar environment (section 1.1.1), and the desire for age diverse living environments often expressed by older people (e.g. Jalava et al., 2017; Özer-Kemppainen, 2005, p. 51; Verma, 2020, pp. 41–42), the importance of such measures is evident.

Nationally, the goal to 'assist [shrinking] municipalities and communities in adapting their property stock to the decrease in demand and in renovating their existing [publicly funded] housing stocks to meet the needs of the ageing population' (Finnish Government, 2019, p. 56) could greatly benefit from increased knowledge on the spatial reserves that exist, and the uses they could serve. Such knowledge might also help promote renovation over demolition and new construction as a solution to underutilized buildings. From the perspective of sustainable use of the built environment this would seem especially important, since in the current government program increased demolition subsidies are presented as a measure of facilitating building stock adaptation immediately following the above quote. Moreover, renovation instead of new construction can help implement housing solutions for older people within the regular housing stock, as recommended by both the Ministry of Social Affairs and Health (STM, 2017b) and the Housing Finance and Development Centre of Finland (ARA, 2019).

More locally, by having a sufficient understanding of the potential uses of their holdings, municipalities and even smaller housing real estate owners are better equipped to develop their properties. In combination with information about local housing needs, the feasibility of revitalizing underutilized buildings can be examined, taking into account various degrees of changes between continued use as is and demolition. Optimally, proactive measures can be taken to avoid functional obsolescence and ensuing underutilization entirely. Here increased understanding of typical designs can also help architects especially in the early stages of the design process (Van Leusen, 1994, p. 274).

On the level of individual households, finding ways of getting ageing people to consider—and act on—the need of home modifications in time has been identified as a key challenge for municipalities in the coming years (Välikangas, 2017, p. 45). In the current action plan for housing for older people 2020–2022 it is listed as one of the main priorities (Ympäristöministeriö, 2020). To this end, the mass customizable accessibility improvement models introduced in the current research could facilitate easier renovation processes and act as a way of clearly communicating the options available. Consequently, more renovations might get done before the need is immediate, thus likely having a greater positive effect (Kajanus-Kujala, 2008). This is especially true if the models were developed further to cover a wider range of individual situations and include e.g. supplementary illustrative material and cost estimates. Considering the multi-stage structure of the full models (article III, pp. 249–251; Kaasalainen, 2015), they are also already a step towards the kind of labor and cost based classification system for renovation measures suggested by Verma et al. (2006, p. 26).

4.3. Reliability and validity of the research

In the current research, assessing the potential for ageing at home in the existing Finnish apartment building stock is fundamentally reliant on the appropriateness of the research material used and its initial characterization processes. Shortcomings in especially the sample of existing apartment buildings could directly compromise any conclusions drawn. Similarly, issues at the characterization stage might invalidate both the methods and the results of the suitability and adaptability evaluations. Correspondingly, this section first discusses the representativeness of the main research samples (4.3.1), then the reliability and validity of the characterization processes for those (4.3.2), and finally the reliability and validity of the suitability and adaptability assessment processes (4.3.3).

4.3.1. Representativeness of the main research samples

The primary **research sample of existing apartment buildings** consisted of 320 buildings, which in turn comprised 8745 apartments (section 2.3.1). The sample was used to characterize the existing apartment buildings and assess their use and adaptation potential. While the sample is substantial in size, and larger than the ones used in existing work on the same stock claiming the concept of 'typical' cases (Mäkiö et al., 1994; Pärnänen et al., 1994; Rantala, 2009, 2008; Sorri, 2006), its direct coverage of the entire corresponding apartment stock is obviously rather low at approximately 1.8% (Official Statistics of Finland, 2019b). Thus, it is important to consider how certain overarching properties of the sample compare to this larger stock.

Firstly, the majority of the sample was collected from 43 neighborhoods in 15 cities (section 2.3.1 and appendix A), potentially introducing regional bias. However, as evidenced by the current research and as supported by existing literature (sections 3.1.2–3.1.5; article II; article IV), the studied building stock is extremely uniform both spatially and structurally. Therefore, there is no reason to believe that the geographical location of the buildings had a significant impact on the representativeness of the sample from the current perspectives. On the other hand, should regional differences exist, it would seem unlikely that they would align with the sample well enough to notably reduce applicability to buildings in the unsampled areas. Furthermore, while the sample is geographically quite extensive, the distribution of buildings in it does roughly correlate with the number of people and apartment buildings present in different parts of the country. Any region specific characteristics present in the sample could thus be expected to approximately correspond to the larger stock

Secondly, in sampling an effort was made to balance the material across the studied year range with only a slight emphasis on the 1970s. The overall building stock, however, is more heavily weighted towards the early to mid 1970s (Kakko, 2011; Laine, 1993; see also article II figure 1). Correspondingly, the other parts of the studied era are somewhat overrepresented in the current sample. Considering that the underrepresented years constitute the peak of the mass production boom, it appears likely that the only impact this might have would be that the larger stock is even more spatially and structurally repetitive than the already quite monotonous sample.

Finally, the sample consisted entirely of publicly funded buildings with an unknown mix of tenure types. As discussed in section 3.1.4 and article II (pp. 222–223), existing literature and statistical comparisons strongly suggest there being little to no spatial or structural difference between publicly funded and privately financed production. Furthermore, the difference in both attributes is lowest during the years with the highest construction volume in the mid-1970s, and for structural properties even displays a declining trend (article IV, pp. 298–299). Similarly, the difference between tenure types appears to be limited to the prevalence of apartments with different room counts, (section 3.1.4 and article II, pp. 224–225). Correspondingly, neither financing method nor tenure type should have a significant effect on the generalizability of the current results when it comes to the dimensioning of spaces, apartment layouts present, or structural systems used. Combining this with the other aspects discussed above, there is no reason to doubt the representativeness of the sample for the current purposes.

The **research sample of existing group homes** comprised a total of 130 group home units in 30 assisted living facilities for older people (section 2.3.2). The sample was used to determine the spatial requirements of assisted living group homes to be used in the adaptability study of existing apartment building floors. In theory any single one of the sampled group home units could be considered representative of existing practice, and thus a suitable candidate for the adaptability study, based on the fact that all of the units were operational at the time of sampling (October 2015), and remained so when checked again in May 2020. Correspondingly, the requirements for the overall representativeness of the sample are fundamentally less strict than in the case of the apartment buildings. However, especially due to the typological research approach employed (section 3.3.1), the topic is still worth addressing.

With the sample consisting of the three largest cities in Finland, geographical coverage is clearly quite limited. Facilities were also only sampled from urban environments. In other parts of the country and in less densely built areas, existing designs might have emerged that were e.g. more spacious. However, considering the already high cost efficiency requirements for care, and the high number of people in need of that care (section 1.1.2), it appears likely that striving for spatial efficiency is and will remain the dominant practice in new construction. Furthermore, while more rural areas are likely to have more land available for construction, and numerically fewer older people, their declining and graying total populations ultimately cause a similar lack of resources and need for efficiency.

The most recent material in the sample is from the year 2015. Although a recheck conducted in May 2020 confirmed all of the studied group homes to still be operational, it was not examined whether they had had renovations, nor were any new facilities constructed since added to the sample. Thus, some of the material used might no longer accurately represent the current situation, and newer facilities might have been designed differently. However, after the time of sampling there have been no changes to the Finnish legislation on housing services for older people (L 980/2012, 2012), nor has acknowledged design guidance (Rakennustietosäätiö RTS, 2013), sparse though it is, been updated. There have been increases in the required number of care personnel per group home resident in intensive sheltered housing (STM, 2017a), but according to the Finnish Institute for Health and Welfare 95% of existing facilities already fulfilled the new requirement before it was set (THL, 2018). Thus there is no reason to expect significant changes in design practice stemming from changes in policy or prevailing guidance. Based on all of the above, it is reasonable to consider the sample a valid representation of the larger stock for the current purpose, the focus being on recurring practice and feasible designs—not in-depth analysis of specific facilities.

4.3.2. Characterization of existing buildings

The drawings used as the main research material for both building types were of varying quality in terms of the original media, ranging from microfilm scans to vector based PDF files. In addition, processing the material involved a large amount of manual work. Thus, there is some risk of unreliability in the initial data recording phase.

Firstly, there is the possibility of erroneous measurements stemming from the material itself. For existing apartment buildings, as there was no image scanner available at the archive, the architectural drawings were photographed. This introduced a varying degree of geometric distortion. To minimize the error caused by this, corrections were made in an image processing program by referencing annotations and other known distances (e.g. widths of stairs and fixtures) on the drawings. Still, the dimensions recorded are unlikely to be completely accurate. The original material was also hand drawn, which adds its own layer of uncertainty. In contrast, the architectural drawings of existing group homes had all either been scanned or archived digitally to begin with. Thus there is no geometric distortion and all drawings were either already in the correct scale or could be easily scaled based on included reference measurements. This enabled precise recording of dimensions to the extent that the original material itself is accurate.

Secondly, there is the risk of input errors. To minimize these, all clear deviations from the typical properties observed were rechecked to ensure that they were in fact outliers, not errors. This of course still does not provide full certainty since recurring errors in data recording could have affected the concept of typical properties itself. However, as the recording processes were very straightforward and the recorded properties are in line with previous literature where such exists (e.g. sections 3.1.2 and 3.1.5), the risk should be very low. Furthermore, considering the amount of cases from which data was recorded, and the current focus on typical properties, any singular errors should not have a notable effect on the overall reliability of the results.

For **existing apartment buildings**, given sufficiently reliable material gathering, processing, and measurement methods as described above, the validity of the results in terms of space specific dimensioning and general structural systems is not a concern. Therefore, how valid the methods used to describe the sample—and by extension the building stock—are is essentially a question of how well the theoretical apartment types represent actual apartments for the current purposes. This representativeness can be further divided into the components of layout, dimensioning, and structural properties.

With layout there is very little room for interpretation: the apartment types are based on all apartments in the sample, all of which had very clear room and function boundaries and definitions (sections 3.1.4–3.1.5). While rare exceptions in connectivity exist, the locations and original functions of habitable rooms are unambiguous, as are those of bathrooms. Thus the only aspect of variation left is the location or lack of a walk-in closet or an additional toilet. Some apartment types (e.g. types 2–1B and 3–1A in figure 13) have a closet presented, as this is the most common scenario, even though a number of actual apartment within these types lack one. Since the walk-in closet is formed by non-structural walls, the impact of this on renovation options is minimal. Similarly, separate toilets are extremely rare (section 3.1.5) and do not introduce additional structural walls.

The typical dimensions recorded for the recurring apartment types are approximations of median values (section 3.1.1). Therefore they do not, nor are they intended to, accurately match all existing real apartments covered by the types. They do, however, provide a picture of a middle of the road situation, based on which e.g. generalizable renovation plans can be designed while taking into account the variation observed in the dimensions. Furthermore, given the repetitive dimensioning and general layouts in the studied stock, (sections 3.1.2–3.1.6), many observations based on the determined recurring apartment types are also virtually guaranteed to apply to the designs not covered by them.

Finally, the structural properties presented are also representative of the most common situation. Most notably, in the adaptation studies all main crosswalls have been marked structural, while this was the case in only approximately three out of four sampled apartment buildings (section 3.1.2). Especially towards the end of the studied era these structural partition walls become rarer due to the proliferation of the BES system (section 3.1.2). Thus, some changes would be easier to conduct in practice than presented here.

Existing assisted living group homes were examined to determine typical properties for use when assessing the repurposing potential of apartment building floors. Therefore, after the reliability related data recording considerations discussed above, the validity of the characterization process depends on how well the recorded properties represent the studied group homes for this purpose. Similarly to existing apartment buildings, these properties can be divided into layout and space specific considerations.

Examining group home layouts through the defined space types, practically all recurring functions were directly accessible from the main corridor (section 3.3.2). Furthermore, no pattern was distinguishable for the placement of specific functions within the studied units, aside from shared spaces tending to be somewhat clustered together (section 3.3.2). These characteristics led to a similar centralized connectivity network for each unit (section 3.4.1, figure 24). When placed adjacent to each other, some of these functions might also have secondary connections between them, which were not recorded, but from the above it is clear that these are not necessary for a unit to function.

Using the concept of functional spaces to combine specific group home functions into space types (section 3.3.3) meant that aside from apartments the spatial requirements for any individual room were not recorded. This grouping did, however, take into account minimum space width, openness to surroundings allowed, and need for a window outside (section 3.4.4.2, table 12). Therefore, the data is sufficiently detailed to assess the ability of spaces on existing apartment building floors to accommodate the typical functions of a group home, even though it could not be used to reconstruct the full room program of a unit.

Overall, the characterization processes for both building types are quite resistant to significant unreliability. While the large amount of manual work increases the risk of singular errors, it also decreases their significance, increases the chances of catching said errors, and decreases the chances for systematic error. As for validity, the descriptive characteristics presented are ultimately quite simple, i.e. mainly straightforward descriptions of layouts, dimensions, and structural properties. Thus, when the samples can be considered representative for the current purposes, results that are reliable are also valid.

4.3.3. Assessment of suitability and adaptability of existing buildings

The suitability or adaptability assessments for both independent housing and assisted living group homes were based on comparing the spaces available in the apartment buildings with the spaces required by the respective housing types. The samples and methods used to characterize the existing buildings are discussed in the preceding sections (4.3.1 and 4.3.2). This section continues onto the spatial comparison processes for each type of housing.

For the **suitability and adaptability of existing apartments for independent housing for older people**, the assessment began with constructing a knowledge base on the spatial properties required through a literature review. This was followed by determining common accessibility issues in the studied apartment stock (article III, table 2). Finally, architectural designs addressing these issues were drafted and applied to a sample of real apartments to assess their adaptability (section 3.2.3).

Due to the highly repetitive nature of the existing apartments, common accessibility issues could be observed by examining a selection of the most common apartment types in light of the initial literature review. Although this obviously does not provide precise figures on the number of apartments where e.g. a certain space is too narrow, it does allow reliably identifying recurring issues, which was sufficient for the purposes of the current research.

Further confirmation for this process was gained from the identified issues matching with existing research on the same apartment stock (Sorri, 2006; Verma et al., 2012).

Drafting the architectural designs relied on interpreting various sources of regulations, design guidance, and other literature. Although these are quite clear on e.g. wheelchair accessible dimensioning, more or less strict requirements for aspects such as furniture and fixtures might change the results of the applicability study. Thus, while the designs do address the accessibility issues identified, they only represent a certain set of possible solutions. Someone repeating the process would most likely not end up with identical designs. However, if adhering to the same design guidelines it is likely that attempting to apply those designs would yield results very similar to the ones obtained here.

For the **adaptability of existing apartment building floors into assisted living group homes**, a quantitative comparison of spaces available and required was conducted. This comprised the subtopics of spatial structure and overall dimensioning (sections 3.4.2 and 3.4.3), availability of suitable spaces for individual group home functions (3.4.4), and availability of suitable spaces for all group home functions simultaneously (3.4.5).

The comparison of spatial structure and overall dimensioning available and required (sections 3.4.2 and 3.4.3) was a simple quantitative process with little risk of error given sufficiently accurate recording of properties from existing apartment buildings and group home units (see preceding sections 4.3.1 and 4.3.2). Likewise, examining the availability of spaces for individual group home functions (3.4.4) required no author interpretation. The assessment could be conducted by simply comparing the number of spaces or pairs of spaces fulfilling certain criteria (e.g. floor area, minimum width) to the requirements of each target function, one function at a time. In contrast to the above, the full group home adaptability study (3.4.5, procedure illustration in figure 27) entailed an iterative process for each adaptation test. As this was done manually, it is possible that in some cases a more optimized solution would have been possible by further rearranging the functions but went unnoticed. Correspondingly, existing buildings may be more supportive of repurposing than the results indicate.

As discussed in section 3.4.6, a real repurposing project would likely have more options for placing the target functions than the methodology employed here covered, such as more comprehensive changes to structural walls. Likewise, the presence or lack of supporting spaces outside the group home would have to be considered. Compromises could also be made on a case by case basis to e.g. the dimensioning of specific functions. Thus, the results provide a general overview of the potential in the stock using a certain set of requirements derived from established practice and regulations. At the same time, as with the other areas of the dissertation dealing with typical properties, they are not necessarily precise per building snapshots. Similarly, the methodology introduced is best utilized to evaluate the adaptation potential in parts of the stock larger than a single building, such as a neighborhood or a city district. Finally, it should be noted that although the Finnish group homes examined appear to be indicative of current local practices, they do not necessarily correspond to best practices.

4.4. Limitations of the research

As established in the previous sections, the characterization of the existing apartment buildings, and all observations directly based on that, are very likely to apply to at least the vast majority of the corresponding Finnish stock. The exception to this might be repurposing entire floors in tower blocks since the adaptation study was only conducted using slab blocks. Based on the spatial similarities between the two building types it would appear that much of the results would apply to both (section 3.4.2), but ascertaining this would require further investigation.

When it comes to applicability in practice, the spatial perspective and scope of the research also carry certain limitations. Even though properties related to dimensioning were examined extensively, other aspects including e.g. the use of materials and colors, the availability of daylight, the acoustic properties of existing structures, or the types and locations of the existing technical systems present were only covered briefly. All of these can have a major impact on both the usability of the spaces for different functions, and to varying degrees their adaptability to those functions and others.

For group home adaptation, not considering the relative locations of the various functions may have resulted in a higher success rate than would be realistic otherwise. Even though the existing facilities exhibited a multitude of layouts (section 3.3.2), and any such layout might be functional on a basic level, in an actual repurposing project it would be vital to consider for example the visual connections within a unit to aid wayfinding, and how certain functions can be placed to minimize noise disturbances (e.g. Day et al., 2000; Hoglund and Ledewitz, 1999; Pollock and Fuggle, 2013).

As an overarching remark on the results, it bears re-emphasizing that even assuming full correspondence between the sample used and the whole stock, most of the current observations concern typical properties. Since a type by definition includes variation (Argan, 1963), not all of the observations apply to every individual building, apartment, or space. Likewise, due to employing a typological approach instead of conducting more detailed single or collective case studies, some rare but interesting characteristics may have gone unnoticed. Based on the current results as well as related literature, however, significant deviations from typical do appear rather uncommon in the studied stock.

Another perspective on individual variation is that in practice the feasibility of adapting a building, and thus ultimately the adaptability of the building, is dependent on not only the building itself but also its context (Heidrich et al., 2017, p. 298; Rockow et al., 2019, p. 284). Therefore what is possible spatially might e.g. not be financially feasible in a certain case, or not make sense considering the types of households the area is suited to. The impact of such context issues was not explored in depth in the current work. In light of the lack of variation in the examined cases regardless of location, however, it should only have an impact on acting on the results obtained, not the results themselves.

Considering context in the physical sense, it is also notable that this dissertation focuses nearly entirely on interior spaces. While the importance of the surroundings is acknowledged, and brief discussion is included related to e.g. views outside and balcony accessibility (section 3.2.3) as well as the feasibility of elevator retrofits (3.1.3 and 3.4.6), such matters were not examined in detail. Nor were typical building mass or function arrangements on the scale of a city block or more studied. Although this does not diminish the spatial observations so far made, some issues or opportunities may have gone unnoticed. For example, analysis of the typical orientations of habitable rooms of different sizes could give further insight into the spatial qualities available through repurposing. On a broader scale, extending the frame of observation to a neighborhood might reveal further opportunities for larger renovation or repurposing projects.

International applicability

From the perspective of international applicability, focusing on the Finnish building stock is a clear limitation of the current work. Utilizing either the methods or the results presented here in the context of another country must take into account local differences that might affect their applicability. However, as noted in the introduction, similarly repetitive, prefabrication heavy post-war mass housing stocks exist in many countries, and they are largely facing very similar challenges. While conducting a comprehensive international comparison was outside the current scope, even a brief study of such housing reveals clear similarities between the Finnish stock and those in numerous other countries—as briefly described below.

In Germany (a–c in figure 31), a significant share of the 'Plattenbau', mass housing built from prefabricated concrete elements, are structurally and spatially very similar to those in Finland (Bundesministerium für Raumordnung, 1992; Trusch, 2009). These are also widely in need of repair, often in shrinking areas with ageing populations (Winder, 2005). In Russia (d), massive industrialized housing production during the Soviet era has left a vast stock of highly standardized buildings, since largely fallen into disrepair (Gunko et al., 2018). A similar legacy also exists in other Post-Soviet states, such as Estonia (e). In Sweden (f) a quarter of the housing stock, including a third of a million apartments in multi-storey apartment blocks of four or more floors, was built during the 1965–1974 'Million Programme' era (Stenberg, 2013, p. 8). There too the construction processes were highly rationalized and industrialized and in favor of prefabrication (ibid.), and the buildings are now largely in need of repairs (Hall and Vidén, 2005, p. 324). Most developments were also large suburban concentrations in previously unbuilt areas (ibid.), again very similarly to other—especially Eastern and Northern—European housing estates (Baldwin Hess et al., 2018, pp. 7–8). Comparable 'million homes' targets were also formed in other European countries, such as Hungary (g), France, and Spain, leading to monotonous mass production especially in the periphery away from existing city centers (Baldwin Hess et al., 2018, pp. 7–9). In addition to these specific examples, it is also notable that the development of the dominant Finnish concrete panel system of the 1970s, BES, was based on a review of approximately 500 international systems (Seppänen and Koivu, 1969). Therefore, similarities between that and the prevalent systems in other countries would seem only logical.

Figure 31. Examples of post-war mass housing floor plans. a/b/c: Germany, Plattenbautype P 1, Plattenbautype QP. Plattenbautype WBS 70 (Trusch, 2009, p. 17); d: Russia, Series 122 precast large panel building (Klyachko et al., 2002, p. 3); e: Estonia, typical 1960s I-464 apartment building (Ai, 2020, p. 45); f: Hungary, precast panel building (Modern Győr, 2014) g: Sweden, 1960s million programme era building (Chhaya, 2017, p. 44) ; h: Finland, typical 1970s prefabricated apartment block (author's research). Plans are to scale with each other, redrawn from above sources and author's own research material.

Finally, the basic composition of a residential building itself leads to a degree of similarity in interior configurations, especially when restricted to multi-storey apartment blocks. The placement of apartment boundaries, the original connectivity layout, and the depth of the whole plan will of course vary between e.g. buildings with a compact stairwell, a side corridor, or a central corridor. However, as all habitable rooms require a window outside, large spaces tend to be located along the facades regardless, in repeating arrangements and with structural walls at regular intervals (Steadman, 2014, pp. 29–34, 46; Van Leusen, 1994, pp. 122, 145). Correspondingly, halls, interior corridors, and stairwells end up in the middle of the building frame, as often do utility spaces such as bathrooms or walk-in closets. Thus any such buildings are prone to having at least rather similar potential space layouts, if not even existing layouts. In a typical oblong slab block this will result in two series of habitable rooms surrounding a central utility core, as is the case in the examples illustrated in figure 31. Based on all of the above, it appears highly likely that at least the adaptability assessment methods presented in the current work could also be applied to many other mass housing stocks than the Finnish one. The resulting findings on adaptability may also be applicable, but they are likely to be more situational due to being largely tied to more specific dimensioning.

5. CONCLUSIONS

This dissertation studied the potential for ageing at home in the Finnish apartment building stock, focusing on mass housing from the 1970s. In particular, the emphasis was on the spatial renovations required and possible in these buildings. The specific forms of ageing at home included were independent apartments and assisted living group homes. Taking a typological approach to building stock research, representative samples of existing apartment buildings and assisted living group homes were examined to characterize their recurring properties. The properties of the apartment buildings, both present and achievable through adaptation, were then compared to the spatial needs of housing the ageing population through multi-case studies utilizing research by design methodology. The above process resulted in a description of the potential in the studied apartment building stock for the chosen use cases as well as a more general overview of its adaptability. Furthermore, a set of methods was developed and presented for conducting similar assessments in other similarly repetitive stocks, or for other use cases.

5.1. Main findings

For independent housing for older people, the typical apartment designs observed in the studied building stock appeared mainly suitable. Although most apartments will require some adaptations to be considered accessible by today's standards, the potential and need for these changes proved to match well. For major spatial changes, the crosswall frame system prevalent in the stock makes resizing most spaces difficult. However, this structural issue mainly concerns habitable rooms, which are the least likely to require such measures thanks to typically quite generous original dimensioning. Usually changes to furniture and fixtures will suffice, or functions can be relocated between these rooms because of the centralized apartment layouts. Conversely, the rooms which most often simply lack space, i.e. the bathroom and the hall, are rarely surrounded by structural walls.

As a similarly positive result, most existing apartment building floors were found to be spatially viable candidates for adaptation into assisted living group homes. All of the studied cases had suitable spaces available for each typical group home function, and most could also accommodate all of the functions simultaneously while still having enough room for a reasonable number of apartments. However, due to the constraints imposed by the existing building frame, much more spacious designs will have to be accepted in adaptation than is typically found in new construction. Considering that the dimensioning in many of the existing group homes studied was found to be at or below the current minimum Finnish guidelines, this is arguably even preferable. Furthermore, since adaptation in place of new construction can both combat vacancies and reduce resource use, a case can also still be made for increased overall efficiency in the use of the building stock.

On the whole, the current results indicate that the Finnish post-war apartment building stock holds vast spatial potential for housing the ageing population. Based on the two types of housing studied, it is evident that this potential covers the spectrum of housing needs from independent apartments up to the more intensive forms of assisted living. Thus, while some new construction remains necessary, better utilization of existing buildings through different degrees of adaptation should often be seen as the primary option. This is especially true in areas where a sufficient number of buildings and dwellings already exists, and the issue is their usability.

Finally, it is important to note that the needs and wishes of older people, like those of people in general, are varied and individual, creating a need for an equally varied range of housing arrangements. Thus the purpose of this research was not and is not to advocate certain specific types of housing or home modifications. Rather, through the distinct, currently common types of housing included, the potential in the existing building stock is presented as a means to respond to a variety of different needs. Although this dissertation focuses on older people with varying levels of disability, improving the accessibility of the built environment is ultimately beneficial to all users.

5.2. Further research topics

As already noted in section 4.4, in addition to the properties of a specific building, the feasibility and success of adaptation also depends on the context. Successful ageing at home for example is not only a matter of offering suitable dwellings, but also requires e.g. sufficient nearby services—care and otherwise—and an environment that supports being active (Verma, 2020). While the changing needs for housing discussed in the introduction of this dissertation comprise a general overview of the context for adaptation within the current scope, further exploration of local situations would be advisable. This would allow identifying typical combinations of spatial reserves and local needs and, on the other hand, local offerings.

Narrowing down the scope from the above, it would also be beneficial to further examine the spatial and functional adaptation potential of an entire building, as briefly discussed in section 3.4.6. Through studying the shared spaces found in existing facilities, complemented by a review of related literature, methodology similar to the current work could be employed. Optimally, both the buildings and their contexts would be studied in connection to each other, to better identify the potentials and requirements of the surroundings as well as how a specific building might address these. This would likely reveal new options and opportunities for building adaptation, such as fully or partially repurposing apartment building floors for use as service centers for the wider community. Here at the latest the connection between interior and exterior spaces, and the need and potential for adaptation thereof, would also have to be studied in greater detail. This should also include balconies as an intermediate space between interior and exterior. Furthermore, to ensure a holistic perspective on accessibility, these wider scale studies should aim to encompass wayfinding and various sensory, wellbeing related aspects such as noise, daylight, and views.

In this dissertation the building adaptability assessment focused on the specific use cases of two types of housing for older people. However, since the spatial characterization of existing apartment buildings is not tied to any specific target function, nor are the adaptability assessments methods presented, the examination could be extended to cover more potential uses. Furthermore, the same approach could be used to evaluate the transformation potential between any spatially compatible pair of building and target function. After all, population ageing is but one cause of functional obsolescence in the apartment stock, not to mention the building stock as a whole. Here it would also likely be useful to consider additional or alternative ways of combining spaces. These should include at least merging or connecting spaces on different floors, as already done by Huuhka and Saarimaa (2018) within the context of housing.

The typology of apartments formed in this research so far was fully precedent based in that only observed recurring layouts were included. However, as noted at the end of section 3.1.4, based on certain patterns among these there is reason to believe that further recurring designs exist in the stock despite being rare in the current sample. To verify this a more extensive sample could be gathered and analyzed. Going a step further, the typology could be extended to cover all apartment layouts theoretically possible in the stock, taking into account the already identified design patterns as well as other properties and boundaries such as structural solutions. Complementing this, samples from similar stocks in other countries could be used both to test the applicability of the adaptability assessment methods employed here and to potentially further extend the typology.

To increase the overall body of knowledge and facilitate practical applications, the datasets formed in the current work could also be supplemented with additional information related to e.g. the costs of the various renovation measures. Through such additions, comprehensive assessments of large sections of the stock from additional perspectives could be conducted with relatively little effort. At the other end of the scale, this would also allow creating more complete mass tailored renovation concepts, which could be used to inform residents and other interested parties of the options available.

Related to the above, the building stock characterization and adaptability evaluation methods employed in the current research each have a large component of quite mechanical data recording. Thus, to reduce the time involved, minimize the risk of human error, and ultimately support their wider use for further research and practical applications, automating some of these processes would be beneficial. This might include e.g. developing a plugin for an existing CAD software to extract and preprocess the relevant data from building information models more easily.

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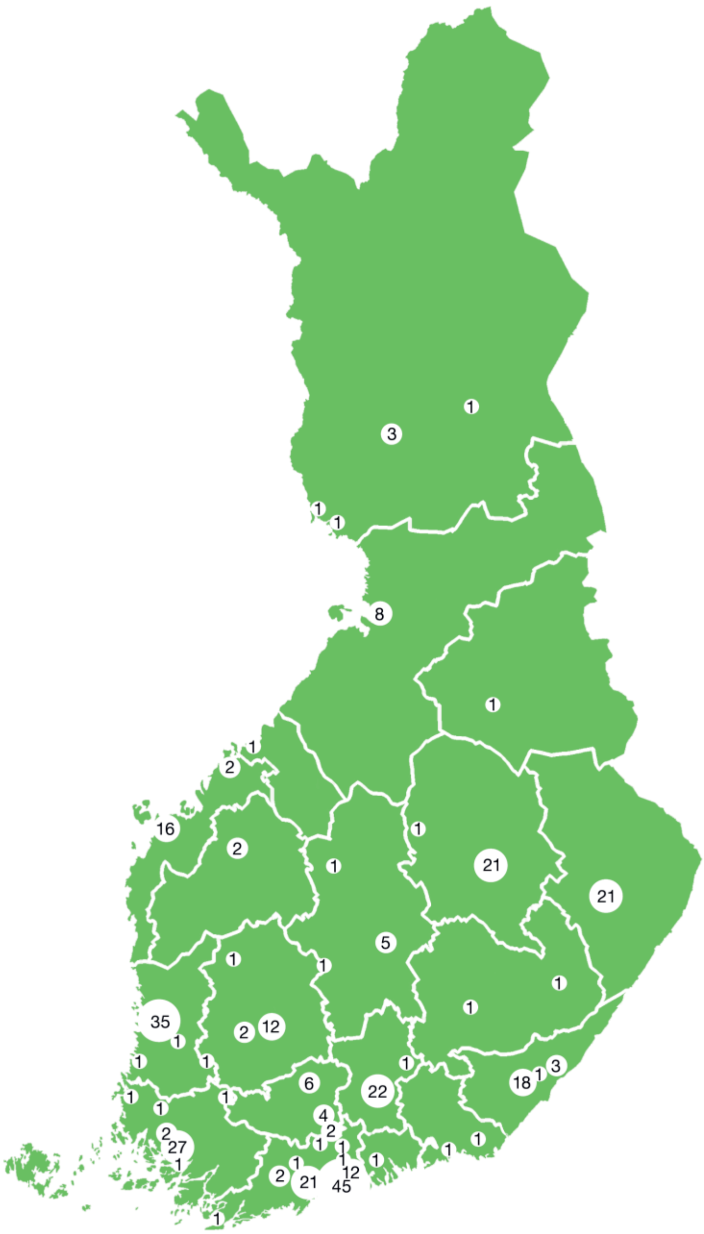
APPENDIXES

Appendix A: Locations and number of sampled apartment buildings



Espoo	21
Forssa	4
Hanko	1
Harjavalta	1
Heinola	1
Helsinki	45
Huittinen	1
Hyvinkää	2
Hämeenlinna	6
Iisalmi	1
Imatra	2
Joensuu	21
Joutseno	1
Jyväskylä	5
Järvenpää	1
Kajaani	1
Karstula	1
Keitele	1
Kemi	1
Kemijärvi	1
Kerava	1
Kokkola	1
Kotka	1
Kuopio	21
Lahti	22
Lappeenranta	18
Lapua	2
Lohja	2
Loimaa	1
Loviisa	1
Mikkeli	2
Mynämäki	1
Mänttä	1
Nokia	2
Nummela	1
Nurmijärvi	1
Oulu	8
Parainen	1
Parkano	1
Pietarsaari	2
Pori	35
Porvoo	1
Raisio	2
Rauma	1
Rovaniemi	3
Savonlinna	1
Tampere	12
Tornio	1
Turku	27
Uusikaupunki	1
Vaasa	16
Vantaa	12

Appendix B: List of sampled assisted living facilities

City	Year of materials	Name of facility (at the time of sampling)
Espoo	2000	Palvelukoti Sylvi
Espoo	2003	Mereo Matinkylä
Espoo	2003	Vire Koti Muurala
Espoo	2003	Vire Koti Uuttu
Espoo	2009	Elämäntalo Aaria
Espoo	2009	Folkhälsanhuset i Esbo
Helsinki	2004	Rudolfin palvelutalo
Helsinki	2005	Madetojan palvelutalo
Helsinki	2007	Hopeatien palvelutalo
Helsinki	2008	Kontulan monipuolinen palvelukeskus
Helsinki	2009	Itäkeskuksen palvelutalo
Helsinki	2009	Roihuvuoren monipuolinen palvelukeskus
Helsinki	2010	Kannelmäen palvelutalo
Helsinki	2011	Syystien monipuolinen palvelukeskus
Helsinki	2012	Kinaporin monipuolinen palvelukeskus
Helsinki	2012	Riistavuoren monipuolinen palvelukeskus
Helsinki	2013	Puistolan palvelutalo
Helsinki	2013	Töölön monipuolinen palvelukeskus
Tampere	2001	Keinupuiston palvelukoti
Tampere	2005	Palvelukoti Suvantopiha
Tampere	2005	Willa Viola
Tampere	2011	Hoivakoti Ratina
Tampere	2011	Koukkuniemen Impivaara
Tampere	2011	Koukkuniemen Jukola
Tampere	2012	Ruusuvuoren hoivakoti
Tampere	2014	Koskikotikeskus
Tampere	2014	Kuuselan seniorikeskus
Tampere	2014	Pispanlinna
Tampere	2014	Pohjolan palvelukeskus
Tampere	2015	Koukkuniemen Toukola

PUBLICATIONS

Article I	Kaasalainen, T. & Huuhka, S. (2020). **Existing apartment buildings as a spatial reserve for assisted living.** International Journal of Building Pathology and Adaptation, 38(5), 753–769. doi: 10.1108/ijbpa-02-2020-0015
Article II	Kaasalainen, T. & Huuhka, S. (2016). **Homogenous homes of Finland: 'standard' flats in non-standardized blocks.** Building Research and Information, 44(3), 229–247. doi: 10.1080/09613218.2015.1055168
Article III	Kaasalainen, T. & Huuhka, S. (2016). **Accessibility improvement models for typical flats: mass-customizable design for individual circumstances.** Journal of Housing for the Elderly, 30(3), 271–294. doi: 10.1080/02763893.2016.1198739
Article IV	Huuhka, S., Kaasalainen, T., Hakanen, J. H. & Lahdensivu, J. (2015). **Reusing concrete panels from buildings for building: potential in Finnish 1970s mass housing.** Resources, Conservation & Recycling, 101, 105–121. doi: 10.1016/j.resconrec.2015.05.017

ARTICLE
I

Existing apartment buildings as a spatial reserve for assisted living

Kaasalainen, T. & Huuhka, S.

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ABSTRACT

Purpose

Ageing populations induce needs to adapt existing housing. With ageing, the number of frail old people, who require assistance in daily life, is also increased. Converting existing housing into assisted living enables them to remain in their community while receiving necessary support and care. The purpose is to investigate whether post-war mass housing is spatially appropriate for adaptation into group homes for older people.

Design/methodology/approach

The research material is attained from Finland. Spatial requirements for group homes are drawn from 130 units built or renovated during 2000–2015. Spatial characteristics of mass housing are mapped from 105 apartment buildings built in the 1970s. The latter are matched with the former by comparing the connectivity of layouts, sizes of units and the numbers and sizes of individual spaces.

Findings

Group homes typically utilize a linear layout, which can easily be created in apartment buildings. Individual spaces of a group home fit apartment buildings effortlessly. Whole group home units mostly prove to be spatially feasible but result in looser dimensioning than is typical in existing units. The mass housing stock can be considered a spatial reserve for adaptation into group homes.

Originality/value

This is the first study to employ a large-scale, multi-case spatial mapping approach to analyze the adaptability properties of mass housing into assisted living. The findings pertain primarily to the Finnish context, but a methodology is presented which can be applied to other countries and also to other spatial functions.

KEYWORDS

Repurposing, adaptability, adaptive reuse, mass housing, population ageing

1. INTRODUCTION

Existing buildings are increasingly seen as spatial reserves for users' changed and novel needs, making adaptation an alternative to new construction (Kohler and Hassler, 2002; Kovacic et al., 2015). A key megatrend sparking these adaptation needs, especially in housing, is population ageing, which is a substantial global phenomenon (Kabisch and Grossmann, 2013; Eurostat, 2019). Finland, the target of this study, is among the countries where population ageing is most prominent. Currently over 22% of the Finnish population is over 65 years of age. By 2040, the projected figure will exceed 27%, putting Finland's population among the oldest in Europe (Eurostat, 2019) and correspondingly in the world (Serrano-Jiménez et al., 2019).

The existing building stock in Finland, as in many other countries, is often considered inadequate in terms of supporting older people living independently, which highlights the need for home modifications (e.g. Jalava et al., 2017; Pettersson et al., 2017; Serrano-Jiménez et al., 2019; Slaug et al., 2020). What is more, with population ageing, the number of frail old people, that is, people requiring assistance in their daily activities, is also increased (Strandell and Wolff, 2019, p. 50). Oftentimes "regular" home modifications will not suffice to meet their needs, and more intensive forms of assisted living, such as group homes, become necessary. In this form of housing, not only does the physical environment accommodate the needs of older people, but professional care is also available. (Reed et al., 2007). Compared to institutional care, assisted living is argued to be both preferred by the residents and more cost-efficient (Afshar et al., 2017; Kovacic et al., 2015).

In Finland, again like in many other countries, post-war mass housing is the main target requiring adaptations to support ageing in place (e.g. Pettersson et al., 2017; Slaug et al., 2020; Verma, 2019). Comprising circa 40% of all Finnish apartments (Official Statistics of Finland, 2019a), it is not only a quantitatively significant part of the housing stock but also substantially inhabited by ageing residents (Stjernberg, 2019). Kaasalainen and Huuhka (2016) have already presented mass-customizable home modification models for making apartments in this type of housing more age-friendly. So, the current study focusses on adaptability for assisted living. The main objective is to assess the spatial suitability of 1970s apartment buildings for conversion into group homes for older people through the following research questions:

1. What are the typical spatial requirements of assisted living group homes?
2. What are the typical spatial structures and dimensions of spaces in 1970s apartment buildings?
3. How adaptable are existing apartment buildings for use as assisted living group homes?

Similar to many countries worldwide (Kabisch and Grossmann, 2013), population ageing in Finland is most pronounced in the areas simultaneously undergoing the greatest decline in total population (Stjernberg, 2019). Under these circumstances, adaptation of the existing stock may very well be the only viable option to improve the physical living conditions of older people, because new construction is economically infeasible. It is also increasingly argued that adaptation should be prioritized over demolition and new construction for environmental and social reasons even where new construction is economically viable (e.g. Huuhka, 2016). When it comes to assisted living, solutions based on adaptation can support ageing in place, which is a widely adopted policy goal (Serrano-Jiménez et al., 2019; Slaug et al., 2020). Ageing in place can help maintain one's place-bound identity and social networks, which are features that are positively connected to an individual's community satisfaction and well-being (Afshar et al., 2017; Fitz et al., 2016; Kovacic et al., 2015).

In the context of post-war mass housing, the economic conditions of adaptations, regardless of the location, are tightened by the fact that the housing being older denotes that it typically suffers from physical deterioration. The technical repair needs have also been considered an opportunity to include ageing in place supporting adaptations into renovation projects that would take place regardless (Jalava et al., 2017; Verma, 2019 Pettersson et al., 2017). Still, it has been asserted that novel and cost-effective methods and concepts must be developed to support making existing neighborhoods age-friendly (Behr et al., 2011; Serrano-Jiménez et al., 2019).

So, the current study introduces an analysis methodology applicable to many contexts, even if the research results pertain to the Finnish conditions. The novelty of the developed method lies in particular in a mass mapping approach, which is based on large data sets. Unlike the usual case-study-based research, which by definition delves into the particularities of a singular instance, the current approach originates from the domain of building stock research (see Kohler and Hassler, 2002). It aims at providing generalizable findings about the adaptability of a large mass of buildings for a given purpose, so its future applications can also encompass building stocks and novel functions other than the 1970s mass housing and the assisted living investigated in the current paper.

2. MATERIALS AND METHODS

Previous research has presented a range of methods for evaluating a building's general adaptability, based on, for example, its structural system (e.g. Rockow et al., 2019). To evaluate the adaptability for a certain function, however, more specific consideration of spaces and their connections is required. Therefore, this study presents a large-scale multi-case study in which the spatial requirements of group homes are compared systematically to the spaces available in existing apartment buildings. For this, two separate samples of building plans were used: a sample of existing group homes and a sample of existing apartment buildings.

The sample of group homes contains architectural drawings for 130 individual group homes in 30 assisted living facilities. It contains both municipal and private service providers' facilities from the three largest cities of Finland. The sample comprises all facilities listed in the cities' online information channels at the time of sampling (October 2015) for which plans were available in the building supervision offices' archives. All of the group homes were either constructed or comprehensively renovated during or after 2000 and are thus indicative of current practices.

The sample of existing apartment buildings contains architectural drawings for 105 apartment buildings from the years 1970–1979. To fit a typical group home layout, sufficient floor area is required (for details, see section 3.1). Hence the study was restricted to buildings with at least two stairwells. To facilitate the study of multiple connected stairwell units, only buildings where the stairwells are in line, that is, the long façades are mainly straight, were included. This is not strictly a requirement for adaptability and was done merely to streamline the study process. Within these criteria, the cases were selected randomly from the archive of the Housing Finance and Development Centre of Finland (ARA), which contains building permit documents for all publicly funded housing projects in Finland. Only residential floors were examined, that is, ground floors with utility spaces were excluded. All residential floors in a building have identical plans, and thus each building is represented by a single floor. Determining the relevant properties of the studied buildings and use cases is a key part of the method developed. Therefore, more detailed descriptions of both samples are presented in the results section (chapter 3).

The study represents building stock research. The developed analysis method draws from network theory, statistical research, and comparative research. The spatial properties of both building types were studied through a network of nodes formed by distinct spaces, similar to the analysis of spatial form in space syntax (UCL Space Syntax, 2020). For these spaces, properties including their dimensions, function, and position in relation to the whole floor and to each other were recorded. This provided a picture of the spatial requirements and the spatial reserve and allowed comparisons of fit from the perspectives of overall layout, individual spaces, and groups of spaces, utilizing a large number of cases. The research process is presented in Figure 1, both as a methodological framework and in relation to the specific research questions and structure of the current paper.

Research phase	Research action(s)	Data source(s)	*In current paper*
Properties of spaces required and available for adaptation			***Research questions 1 and 2***
1. Determining connectivity layouts required and available.	Forming connectivity graph(s) of required layouts.	Existing buildings, known requirements.	*Formed manually based on existing buildings and literature.* *Ch. 3.1*
	Forming connectivity graphs of available layouts.	Existing buildings.	*Formed manually based on existing buildings.*
2. Determining total area required and available.	Recording area(s) required.	Existing buildings, known requirements.	*Recorded manually based on existing buildings and literature.*
	Recording area(s) available.	Existing buildings.	*Recorded semi-automatically based on existing buildings.*
3. Determining suitable adaptation cases.	Comparing connectivity graphs and recorded areas.	Phases 1 and 2.	*Connectivity fit confirmed visually. Areas compared manually to exclude unsuitable cases.*
4. Determining properties of individual spaces required and available.	Recording relevant properties required by individual functions.	Existing buildings, known requirements.	*Dimensions recorded manually based on existing buildings, other requirements based on literature.* *Ch. 3.2.1*
	Recording relevant properties of individual spaces available.	Existing buildings found suitable (phase 3).	*Dimensions, relative locations, and connectability recorded semi-automatically based on existing buildings.* *Ch. 3.2.2*
Fit between spaces required and available for adaptation			***Research question 3***
5a. Determining adaptability for individual functions.	Comparing spaces required by individual functions to all spaces available.	Suitable existing buildings (phase 3), properties of individual spaces (phase 4).	*Fit compared semi-automatically based on dimensions and numbers of spaces.* *Ch. 3.3.1*
5b. Determining adaptability for full repurposing.	Comparing spaces required by all functions to all spaces available.	Suitable existing buildings (phase 3), properties of individual spaces (phase 4).	*Fit compared semi-automatically based on dimensions, numbers, relative locations, and connectability of spaces.* *Ch. 3.3.2*

Figure 1. Methodological process of the research. Recording and/or comparison of properties can be either automated or manual.

2.1. Generalizability

To evaluate the adaptation potential and thus the spatial reserve in the larger building stock, representativeness of the samples must be considered. In previous research (Huuhka et al., 2015; Kaasalainen and Huuhka, 2016), samples of 276 and 320 buildings from the years 1968–1985, both of which included the 105 buildings in this study, were extensively compared to the corresponding Finnish housing stock and found highly representative. Furthermore, it was noted that in addition to the highest construction volume, the 1970s had the greatest degree of repetition in building designs. Similar research does not exist for group homes. However, as their sample is reasonably large and covers multiple cities and service providers, it is considered to provide a sufficient perspective into the current state. For both samples, the repetitiveness observed suggests applicability of the results outside the studied material.

3. RESULTS: ADAPTABILITY OF APARTMENT BUILDINGS TO GROUP HOMES

3.1. Layout and total area compatibility

Linear layouts like the one in Figure 2 (left) were observed to comprise the vast majority (77.7%) of existing group homes. In addition, 10.8% consist of a small loop from which linear wings extend, and 11.5% are nonlinear. Consequently, the repurposing part of this study focusses on the linear layout, where functions are arranged along a central corridor and accessed from it. Each main function (for details, see section 3.2.1) typically has only a single access point to the corridor. No recurring patterns for the location of the main functions were found in the sample.

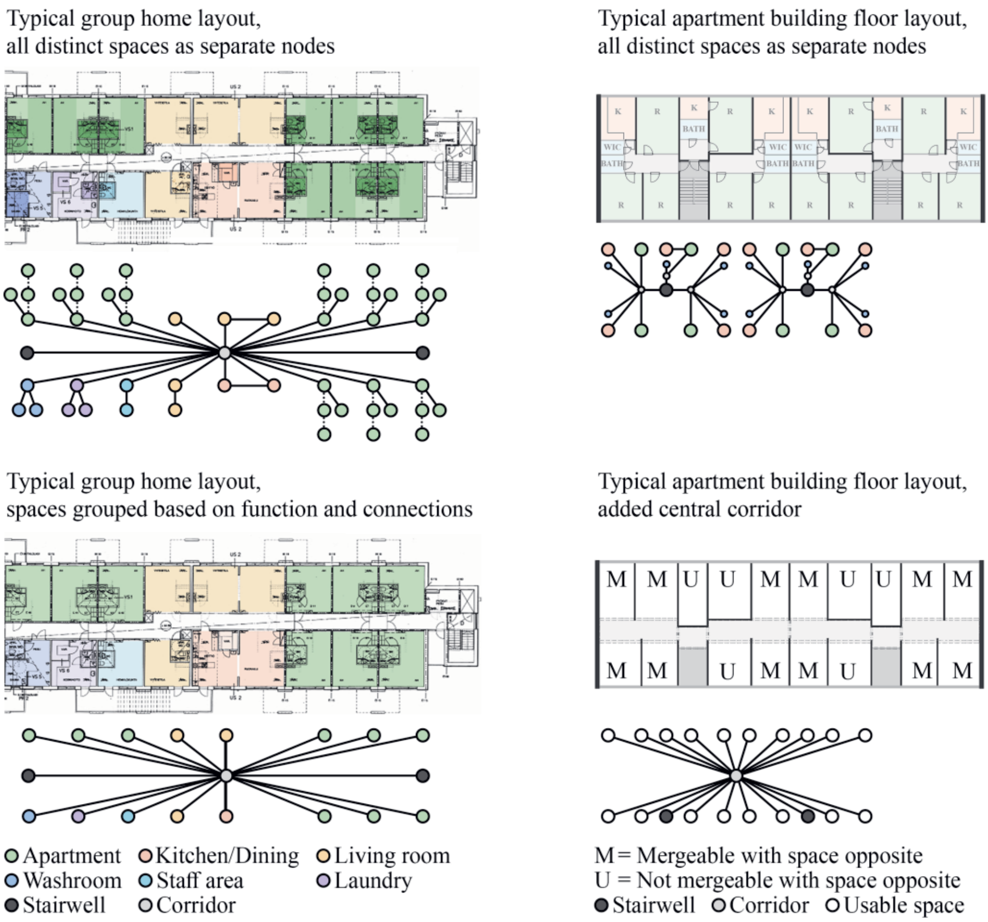

Figure 2. Spatial structures of typical group homes and apartment buildings. Group home main functions with a single corridor access point are consolidated into space groups.

For the existing apartment buildings, the examination of spaces includes the addition of a central corridor, necessary for the conversion into a linear layout group home (Figure 2, right). These buildings proved highly propitious for this addition: the corridor aligning with original stair landings – and consequently the apartments' entrance halls and bathrooms or walk-in closets – maximizes the usability of the existing spaces and minimizes the effect of load-bearing cross-walls.

In this study, it is expected that for accessibility reasons (elevator retrofits), the stairwells will need to be renewed regardless, which allows arranging an access through them. The stair landing could, however, also be bypassed by routing the corridor through the adjacent spaces, even though this slightly complicates the layout and reduces the area available for other uses. The minimum acceptable width for the corridor, excluding, for example, doorways in cross-walls, is 1800 mm for two wheelchairs to pass (Kilpelä, 2019). If this requirement exceeds the original hall width, space is taken primarily from the side with no shear walls parallel to the corridor.

As the existing apartment buildings are considered here as targets for comprehensive adaptation and renovation, their spatial structure is evaluated based only on the location of load-bearing walls, to which limited changes are possible, such as creating doorways. All of the buildings in the sample, like most buildings from the period (Huuhka et al., 2015; Kaasalainen and Huuhka, 2016), have a cross-wall frame, that is, load-bearing cross-building walls. Consequently, most spaces along the long façades have a load-bearing wall between them – always between apartments, and in 77.1% of the sample buildings also within apartments. Taking into consideration the structural system and the addition of a central corridor, for the purposes of this study, the spatial structure of an existing floor can thus be expressed by describing the dimensions of existing spaces along the long façades and whether spaces opposite to each other can be merged across the corridor, that is, whether there is a longitudinal shear wall separating them. The load-bearing walls do not always extend straight across the building frame (see the end of building apartments in Figure 2). In such cases, mergeability is evaluated between the spaces that share the most width between them. Due to the central corridor layout, the location of spaces along the façades has no effect on connections between functions. This is evident in Figure 2 (bottom), where all spaces in both building types connect directly to the corridor.

Comparing the two research samples, two group home sizes (8 and 13 residents) were found sufficient to cover the common amounts of floor area available in apartment buildings. In Figure 3, the black bars show the distribution of floor areas in apartment buildings, while the shaded areas indicate interquartile ranges (IQR, middle 50%) of floor areas for the two group home sizes. IQRs were used to avoid evaluating adaptability using extreme examples. All floor areas consider non-corridor areas only. For existing group homes, these were measured directly from plans. For apartment buildings, the adapted layouts with corridors retrofitted were considered.

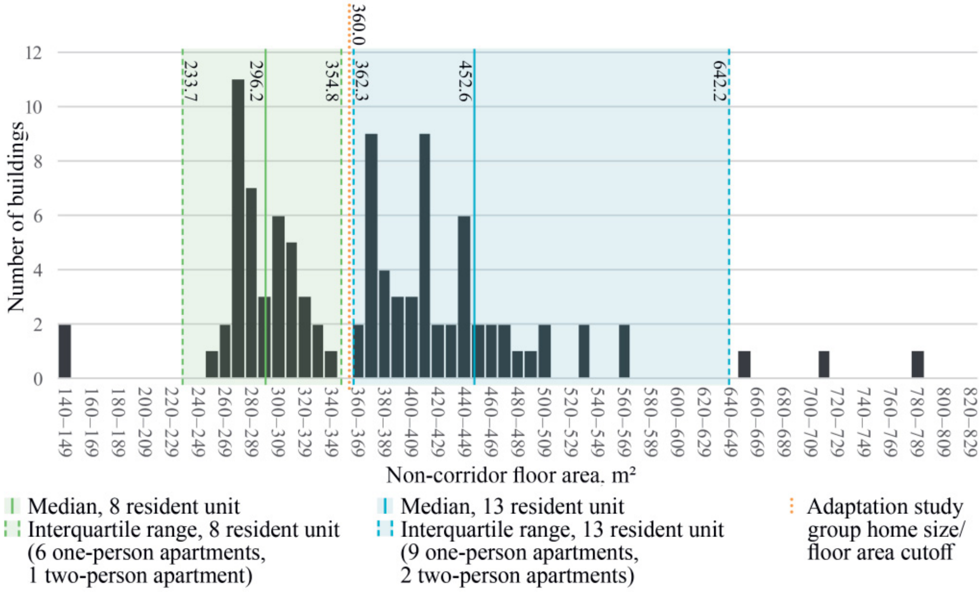

Figure 3. Non-corridor floor areas on apartment building floors (black bars) and interquartile ranges for 8- and 13-resident group homes (shaded areas).

Of the apartment building sample, a total of 95.2% (100 buildings) were found size-wise suitable for 8- or 13-resident group homes. Corresponding to the IQRs for these group home sizes, 360.0 m2 of apartment building floor area was chosen as the dividing line between the group home sizes used for the adaptation study. This resulted in 43 8-resident cases and 57 13-resident cases for the spatial adaptability evaluation. These also correspond closely to Finnish design guidance and general North European practice, where sizes typically range between 7 and 15 residents. (ARA, 2015; Rakennustietosäätiö, 2013; Regnier and Denton, 2009). The mean and median for the research sample are 14 residents. Thus, in terms of overall size and layouts, the existing apartment buildings were found to suit current group home designs.

3.2. Properties of existing spaces

3.2.1. Types and dimensions of spaces in group homes

Table 1 (left) presents the space types found in the studied group homes. Nearly all group homes proved to contain the same selection of general space types. In the vast majority of cases, the kitchen is home-like and used for making, for example, breakfast, while the main meals are delivered from elsewhere. The category of "other" spaces mostly contains small technical spaces and, very rarely, other small non-essential functions. The areas for most space types vary based on the number of group home residents.

Table 1. Space types and non-corridor floor areas for 8- and 13-resident group homes. Areas are based on group homes of similar size (±1 resident), except for apartments which include all apartments in the sample (N=1421 for one-person, N=168 for two-person).

Space type	Specific functions included	% of group homes space type exists in	Area (m²), 8-resident group home				Area (m²), 13-resident group home				Min. width (mm)	Must have window
			IQR lower bound (min)	Median (mdn)	IQR upper bound	Sampled group homes	IQR lower bound (min)	Median (mdn)	IQR upper bound	Sampled group homes		
One-person apartment	Apartment for a single resident, with bathroom.	100.0%	20.6	23.6	*25.1*	130	20.6	23.6	*25.1*	130	3000	Yes
Two-person apartment	Apartment for two residents, with bathroom.	62.2%	26.5	29.8	*35.8*	130	26.5	29.8	*35.8*	130	3000	Yes
Shared living room	Lounges, multi-purpose rooms.	100.0%	22	40	*55.5*	11	40	60.5	*117.9*	54	3000	Yes
Shared dining and kitchen	Dining and kitchen areas.	100.0%	16	19.5	*34.5*	11	27.5	39.5	*55*	54	3000	Yes
Shared washroom	Washroom, toilet, sauna.	77.7%	19	19.5	*22.3*	6	19	24.5	*24.5*	41	2000	No
Laundry	Laundry, drying room, utility room.	95.4%	7	13	*13.5*	9	12	13	*20.5*	53	2000	No
Staff area	Office, staff changing room, staff toilet.	100.0%	11.9	22	*27*	11	13.8	25.5	*54.9*	54	2000	No *
Storage	General and medicine storage, cleaning, rinsing room, waste.	100.0%	5.1	6	*10.8*	11	9	12.5	*66.1*	54	–	No
Other	Technical spaces, shared computer area.	71.5%	3	4.5	*4.8*	7	3	4.8	*5.5*	35	–	No
Total area for shared spaces			83.9	124.5	*168.2*		124.3	180.3	*344.4*			
Total area with apartments			233.7	296.2	*354.8*		362.3	452.6	*642.2*			

* Offices not for long-term working.

In the adaptability study, the median values given in Table 1 are considered desirable while the IQR lower bound is considered the minimum. Including the most tightly dimensioned first quartile would likely include poorly functioning spaces, as even the IQR lower bound often falls below current recommendations. IQR upper bounds are presented for reference but were not used to exclude suitable spaces. In some cases, this creates somewhat loose dimensioning, which is discussed in section 3.3.2. In addition to sufficient area, different functions have different needs for windows and minimum space width. Table 1 also presents the requirements used for these in the adaptability study, drawn from Finnish building regulations and officially recognized design guidance (Kilpelä, 2019; Rakennustietosäätiö, 2013; Ympäristöministeriö, 2017a).

3.2.2. Dimensions of spaces in apartment buildings

As described in section 3.1, existing spaces on apartment building floors are formed by the façades, load-bearing cross-walls and the retrofitted central corridor. The widths of these spaces were observed to vary around three measurements: 3,000, 3,600 and 4,400 mm, with 3,600 mm being overwhelmingly the most common. The distribution of depths is much less focused, mainly ranging from 2,800 to 6,100 mm. For combinations of width and depth, the most common space sizes are approximately 3,600 × 3,200 mm (or reversed) and 3,600 × 5,100 mm. Accordingly, the space sizes peak around 12 and 19–20 m2. Thus, most spaces fulfil the dimensional requirements of the various group home functions: 98.6% are at least 2000 mm wide and deep, exceeding the minimum set for utility spaces (see Table 1). 74.6% are at least 3,000 mm wide and deep, making them large enough for all functions given sufficient area.

3.3. Spatial adaptability assessment

Retrofitting the central corridor enables the apartment buildings to have the desired connectivity layout for a group home (see section 3.1). In addition, an uncompromised adaptation requires that (1) suitable spaces for each individual function exist, and (2) there is a sufficient number of these spaces. If suitable spaces do not exist, adaptation can be very difficult or costly, requiring substantial changes to the load-bearing structure. If there is merely an insufficient – but reasonable – number of spaces, a smaller group home can still be created. Thus, this section looks first into the availability of suitable spaces for the various functions of a group home (section 3.3.1). Then, it is examined whether these functions can be placed alongside one another without running out of suitable spaces (section 3.3.2).

3.3.1. Single function adaptability

The findings indicate that a major challenge in repurposing apartment buildings into assisted living is fitting reasonably sized apartments within the boundaries of the existing structural layout. Only rooms at least 3,000 mm wide can be used as the main residential rooms of an accessible apartment (Rakennustietosäätiö, 2013). Figure 4 shows that a one-person apartment can be formed either by fitting both the main room and the bathroom into a single existing space (A) or by placing them into adjacent spaces (B and C). Multiple adjacent one-person apartments can be placed using principles D and E. In principle D, the hall as shown is then replaced by the bathroom for one apartment. In principle E, the hall is made public space or split between the apartments. Two-person apartments can follow principles A–C directly, or a larger layout with separate main rooms can be formed using principles D–F.

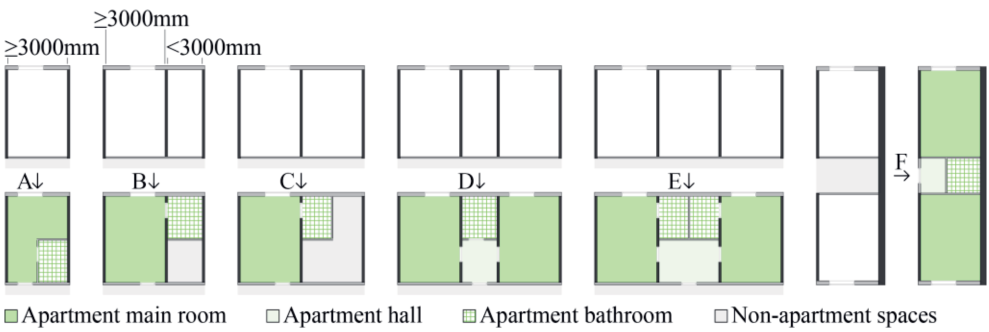

Figure 4. Adaptation principles for forming apartments utilizing existing spaces.

Using the adaptation principles in Figure 4, Table 2 shows the number of buildings in the sample where suitable spaces were found to exist and the number of buildings that were observed to have enough such spaces for a targeted group home size corresponding to the floor's total area. All studied buildings could fit the target number of apartments when placed without the common functions. In most cases, consuming more than one existing space per apartment was required (i.e. principle A was not feasible). Even though a number of apartments typical to new construction were unattainable in most buildings (see section 3.3.2), this analysis shows that the individual spaces themselves do not preclude successful apartment design in the adaptation.

Table 2. Number of buildings with spaces suitable for apartment creation with median and minimum dimensioning (N = 100). With principles D–F (Figure 4), area is always above median.

Adaptation principle used	Single room, bath included (A)		Single room, separate bath (B or C)		Two rooms, shared bath (D)	Two rooms, two baths (E)	Two rooms, end of floor (F)
Dimensioning used	**Mdn**	**Min**	**Mdn**	**Min**	**Mdn**	**Mdn**	**Mdn**
Single-person apartment							
Buildings with any suitable spaces	23	46	86	100			
Buildings with enough suitable spaces	1	16	63	92			
Two-person apartment (single main room)							
Buildings with any suitable spaces	8	15	20	42			
Buildings with enough suitable spaces	8	15	20	42			
Two-person apartment (two main rooms)							
Buildings with any suitable spaces					66	100	87
Buildings with enough suitable spaces					66	100	85

Unlike apartments, the common functions of a group home vary greatly in their need for privacy. Shared living room, dining and kitchen areas can be – and often are – open towards the corridor and each other. So, they can be formed by merging spaces across the central corridor. Other functions need closed spaces and therefore require one or more spaces on one side of the corridor or at the end of it. Staff and storage areas can be spread around the layout as individual spaces of suitable size. All apartment buildings in the sample could fit all group home functions using minimum dimensioning either as a single space, a combination of multiple spaces or both (Table 3). Most functions were found to fit rather well even using the larger, median dimensioning. Thus, as with apartments, it can be concluded that the availability of spaces for any individual function does not prevent successful adaptation.

Table 3. Number of buildings with suitable spaces for common areas with median and minimum dimensioning (N=100).

	Single space		**Merged space**		**Two separate single spaces**		**Separate single & merged space**		**Two separate merged spaces**		**Three separate single spaces**	
	Mdn	**Min**	**Mdn**	**Min**	**Mdn**	**Min**	**Mdn**	**Min**	**Mdn**	**Min**	**Mdn**	**Min**
Shared living room	0	17	3	48	33	76	54	99	91	99	91	100
Shared dining and kitchen	32	48	48	99								
Shared washroom	46	86	98	98								
Laundry	100	100	*	*								
Staff area	29	100	98	98	100	100	*	*	*	*	*	*
Storage	100	100	*	*	*	*	*	*	*	*	*	*
Other	100	100	*	*	*	*	*	*	*	*	*	*

* Possible but unnecessary.

The shared living room proved to be the hardest common function to fit, because it is a relatively large space. No existing single space was found to be large enough for a median-sized living room. A space for a minimum-sized living room existed in every sixth building – exclusively in the 8-resident cases. One large living room can, however, be replaced with multiple smaller ones. This is also common in the existing group homes: 63.3% have more than one living room. Moreover, multiple smaller living rooms may support a sense of hominess often lacking in these facilities (Reed et al., 2007; Regnier and Denton, 2009).

In most cases, placing the dining and kitchen area required merging existing spaces, although many buildings were also observed to contain a suitable single space. Theoretically, kitchen and dining could also be placed in separate rooms. For this to be practical, though, the spaces would have to be adjacent to one another, connectable through a large retrofitted doorway.

The shared washroom was found to fit in a single existing space in most buildings using minimum dimensioning and in nearly half the buildings using median dimensioning. Utilizing merged spaces requires them to be located at the end of the building to avoid thoroughfare – this was possible at both ends of 82 buildings and at one end of 98 buildings. Also, compared to the living room, dining and kitchen areas, which require large uniform spaces, partition walls are less likely to pose a problem for washrooms, so even non-mergeable, adjacent spaces could often be useable.

Laundry, storage, and other areas for both group home sizes are all small enough to fit in available single spaces. Especially the latter two are also propitious ways of utilizing areas left over by other functions, as even narrow spaces are fit for them and they can be distributed around the group home.

All buildings proved to allow minimum-sized staff areas without merging spaces, and nearly a third even fit median-sized ones. As with the washroom, merged spaces at the ends of the building can be utilized, allowing median dimensioning in the same 98 buildings. Additionally, splitting staff areas into multiple separate spaces is also possible, enabling median dimensioning in all 100 buildings.

3.3.2. Full floor group home adaptability

When studied separately, each of the 100 buildings could accommodate the required number of apartments and each common function. However, as most of these functions compete for the same spaces, the final step is to examine how often and how well all of them can be placed together, still fulfilling all individual spatial requirements. This determines the degree of compromise in the adaptations compared to new construction.

When evaluating the adaptability of an apartment building into a full group home, common functions were placed first, since they essentially define a group home. When needed, compromises were made in the number of apartments, which only affects the efficiency of the design. Figure 5 presents this procedure, alongside an example of an existing building layout before and after adaptation. All functions were placed using minimum dimensioning, since the individual placement studies (section 3.3.1) already demonstrated that very few buildings could accommodate median dimensioning.

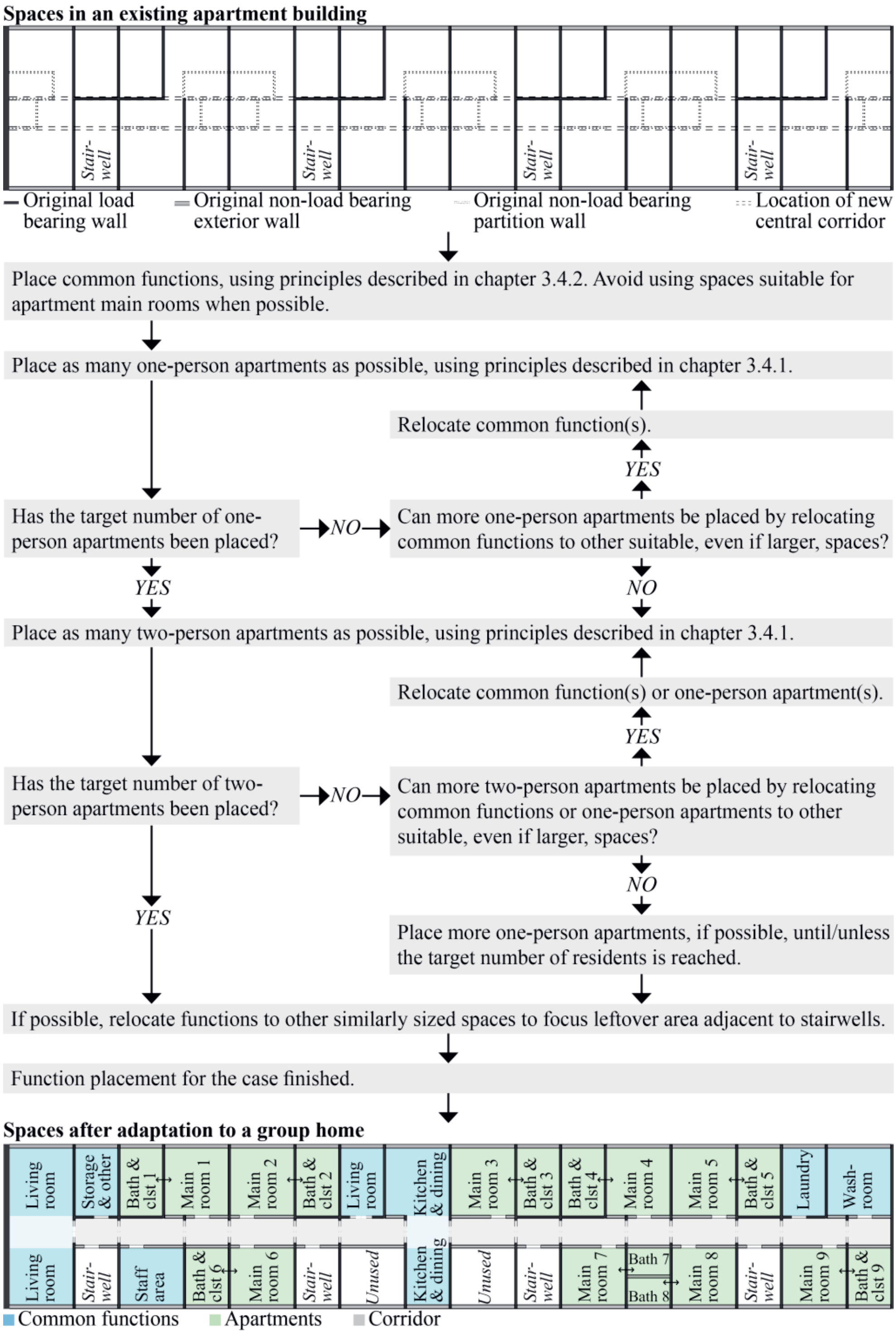

Figure 5. Function placement in the full group home adaptability study.

Most existing apartment buildings were found to not accommodate the target number of apartments, although there were also many that did. Of the 43 cases targeting 8 residents, 25 fit all one-person apartments and 37 fit all but one. For 57 cases targeting 13 residents, the corresponding figures were 16 and 27, while 44 fit all but two one-person apartments. Of all 100 cases, only ten could fit all two-person apartments – six 8-resident and four 13-resident cases. In many, though, increasing the resident number by adding more one-person apartments was possible. On average, cases aiming for eight residents could fit six, and cases aiming for 13 residents could fit eight.

Comparing facilities of equal resident count, the group home designs created in this study by adaptation used on average 128.5% of the floor area used by existing facilities. On the existing apartment building floors, placing all possible group home functions used on average 84.8% of the available non-corridor floor area. If the leftover area would be used for more shared or utility spaces (as it is not suitable for further apartments), the area used by the adaptations would reach on average 151.8% that of the existing facilities. Some of the leftover spaces result from the current method, which excludes combinations of spaces requiring larger structural changes. In practice, some side-by-side spaces might be combined into, for example, a living room by replacing one load-bearing wall with a compensating beam and columns, thus potentially allowing a rearranged layout with more apartments. As 91.4% of the leftover spaces were adjacent to a stairwell – directly or through each other – using them for non-group home functions would also appear largely feasible. In either case, most adaptations created herein proved rather loosely dimensioned compared to the existing facilities.

Comparing non-corridor floor areas per resident, the amount of 31.6–66.8 m2 (median 45.4 m2) in the adapted cases is mostly within the variation found in the existing facilities, 19.5–52.2 m2 (median 36.0 m2). Naturally, the issue of leftover spaces applies here too, potentially increasing the area per resident used to 37.1–99.8 m2 (median 53.8 m2). For reference, Finnish design guidance recommends at least 45 m2 per resident, including corridors but excluding some storage and technical spaces (Rakennustietosäätiö, 2013), which based on the studied group homes equals approximately 37 m2 non-corridor floor area.

The main obstacle for spatial adaptation proved to be the share of existing spaces narrower than 3,000 mm (25.4%), unsuitable for use as apartment main rooms or as shared living, kitchen or dining areas. This made fitting a high number of apartments without significant changes to load-bearing walls challenging and thus creating groups homes as efficient as typical new construction mostly infeasible. Accepting a minimum width of 2,800 mm for these functions would reduce the share of unsuitable spaces to 13.2%, greatly increasing adaptation options.

Despite the challenges noted earlier, as a whole, the existing apartment buildings proved quite flexible for adaptation into group homes. Most existing rooms were found to be rather spacious compared to current construction, and their straightforward placement along the façades, as follows from the cross-wall frame, provides many options for placing functions. The central corridor design was mostly found to require very little changes to load-bearing structures – even doorways are often suitably placed. The connectivity of such a layout means that passage through rooms does not become an issue, which supports easy adaptability for different uses (cf. Herthogs et al., 2019; Leupen, 2006). Overall, existing apartment buildings can be concluded to hold a large reserve of spaces suitable for assisted living with minor modifications, but most adaptation projects will have to accept more spacious dimensioning compared to current new construction.

4. CONCLUDING DISCUSSION

This paper investigated the adaptability of Finnish post-war mass housing into assisted living group homes and in doing so, introduced a novel methodology for studying the adaptability of building stocks for specific new functions. The existing group homes were found to mostly utilize linear layouts with recurring selections of spaces. The layouts of existing apartment buildings were likewise observed to be repetitive. Taking into consideration the typical structural and spatial properties and the ways of allocating spaces for different uses, all apartment buildings were determined to contain suitable spaces for the various individual group home functions. Adaptation into full group homes also proved mostly feasible but resulted in less spatially efficient designs than is typical in current practice. Since adaptation can combat vacancies and replace new construction, it is certainly worth considering even from an efficiency perspective, as the extended building life cycles can enhance resource efficiency. The added spaciousness can also offer benefits from a quality of life perspective. In fact, the more loosely dimensioned adaptations can implement best practice recommendations for resident numbers and sizing of spaces better than the existing facilities.

The study shows that adapting the existing apartment building stock is a spatially viable alternative to new construction to provide assisted living, tightly integrated into the existing urban fabric, for the ageing population in Finland. In practice, the results can be used for estimating the adaptation potential of the existing housing stock as an alternative to new construction in a preliminary manner when new assisted living units are being planned, in combination with information about population, vacancies and housing needs in the area. However, repetitive post-war mass housing and the need for housing solutions that support ageing in place are by no means uniquely Finnish phenomena. Spatially and structurally similar prefabrication-heavy housing stocks exist across the globe (Alonso and Palmarola, 2019). They too may form substantial spatial reserves for adaptation. Such stocks are often situated in circumstances similar to the mass housing in Finland, that is, in areas with ageing populations and shrinkage, vacancies or otherwise tight economic conditions (e.g. Kabisch; Grossmann, 2013), where building adaptation could help address multiple pressing challenges at once. So, the presented approach, which provides a cost-efficient way to assess the conversion capacity, can help researchers map out these potentials in other countries, too.

To this end, the study's contribution consists not only of the findings pertaining to Finland but also of the developed methodology, which draws from network theory, statistical methods, and comparative research. In this study, the methodology proved both effective and efficient in studying the adaptability of a large mass of buildings at once. In contrast to case studies – the conventional methods of architectural adaptability studies – the introduced stock approach combines a sufficiently detailed level of examination with wide generalizability of results. The success of the approach relies on identifying the representative features of both the stock to be adapted and the desired new function, which requires archival drawings to be available and sufficiently large data sets to be used. In this regard, identifying saturation, that is, the point where the findings become repetitive, is the key.

In the absence of methodologies like the one presented in this paper, case studies have been used in the past to proclaim general applicability, even if their findings are by definition not meant to be generalized. Thus, the current study provides one solution to bridge a yawning methodological gap. Recording the number and properties of spaces as simple network allows easy evaluation of adaptation potentials for various uses, also beyond the ones studied in the current paper. Due to the pressing societal need for older adults' housing solutions in Finland, the current research has focused on assisted living. However, in future this method could also be utilized to assess the spatial reserves in other building stocks for other kinds of conversions. The methodology in itself is suitable for numerous applications, for example, from offices to housing or vice versa, as long as both the old and the new functions have a similar general spatial structure. This is to say that the method is fit for assessing adaptability from rooms to rooms or large halls to large halls, but not from rooms to halls or vice versa. Such conversions, which require plenty of added partitions or changes to existing load-bearing structures, may still be spatially and technically feasible, but the current method is not fit for evaluating that without further development.

The strengths of the approach presented in this paper lie in informing policy- and decision-makers about the hidden spatial adaptation potential of an entire stock. This way, the findings can help set policy goals in relation to prioritizing adaptation over replacement or vice versa. To determine the case-specific circumstances for the adaptation in any individual case, such as the technical or economic conditions, more detailed examination through case studies will still be needed. When it comes to the current study's findings, though, it seems clear enough from the spatial adaptability point of view that policymakers seeking to address the housing needs of ageing people should first and foremost consider the existing spatial reserve, in particular in declining municipalities, before introducing ideas of new construction.

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ARTICLE
II

Homogenous homes of Finland:
'standard' flats in non-standardized blocks

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ABSTRACT

Several authors have successfully created and employed vintage cohorts and housing typologies in research addressing energy renovation needs in the existing dwelling stock. This paper suggests that the idea of types would be useful in creating living quality related renovation and adaptation concepts for homes as well. Such concepts could be used for increasing accessibility and individuality of flats and easing life in cramped conditions by means of design. Therefore, the study tests the approach by examining flats' plan design in one cohort: Finnish 1960–80s dwelling stock. The research material consists of plan drawings for 320 apartment blocks with 8745 flats in 51 cities. The study results in recognizing 18 flat types, which are based on ten basic layouts, covering over 80% of all flats in the research material. Although the housing production of this era was characterized by cost-efficiency and industrialized prefabrication technologies, the result can be deemed somewhat surprising. This is because the buildings or their layouts were factually never standardized in Finland, only the production technology was. The identified flat types are estimated to cover as much as one-third of all existing Finnish flats. These findings provide future opportunities for creating new mass-tailored renovation concepts.

KEYWORDS

Apartment buildings, building research, housing stock, representative archetypes, typology, vintage cohorts

INTRODUCTION

Since Niklaus Kohler and Uta Hassler published their widely cited 2002 paper 'The building stock as a research object,' research interest in the existing housing stock has skyrocketed. As Kohler and Hassler (2002) anticipated, the focus is shifting from new construction to stock management. This is hardly surprising, as the amount of annual new construction represents only a few percent of the whole stock in countries with mature housing stocks, such as Finland (Hassler, 2009). However, to create sustainable policies for managing the existing housing stock, sufficient knowledge about that stock is first needed. Obviously, the complexity and vastness of the building stock makes it a challenging research object (Kohler & Hassler, 2002). Many authors have successfully employed vintage cohorts – extracts of the stock characterized by building type and construction decade – in structuring the research work.

With stock management as the new paradigm, the research interest underpinning the creation of vintage cohorts lies, naturally, in life cycle extension. What kind of information should be included in a cohort depends on the intended use of the data. The research has so far encompassed especially the energy consumption of existing buildings together with the parallel need for refurbishment (Kohler, Steadman & Hassler, 2009). For instance, Theodoridou, Papadopoulos and Hegger (2011) have presented a typological classification for Greek housing to promote energy renovations; Famuyibo, Duffy and Strachan (2012) have formed types from the Irish housing stock that include the building type, structures and U-values to form a basis for policies on retrofits; and Holck Sandberg, Sartori and Brattebø (2014) have processed the Norwegian dwelling stock into five age cohorts and two building types in order to investigate future energy renovation needs. Muraj, Veršic and Štulhofer (2014) have taken the approach even further by presenting 'model buildings' with typical plan layouts and façades to portray blocks of flats from different periods.

However, obsolescence is not only a question of technical performance (Thomsen & van der Flier 2011). It is also a matter of changing needs and preferences that are rooted in demographic changes and evolving housing cultures. When a housing stock does not respond to these needs, 'social obsolescence' may occur. According to Kohler and Hassler (2002), this phenomenon has already led to vacancy problems and demolitions of even recently refurbished blocks in Central Europe. For instance, the demolition of the infamous Biljlmermeer housing estate in Amsterdam has been taken as evidence of the failure of the modernist housing ideals. To understand such phenomena better, housing stock studies should also aim at creating in-depth knowledge about the qualities of existing homes themselves, not only the structures that surround them. For example, knowledge on flat distribution, room distribution, flat layouts and room configurations could be highly useful for facilitating home modifications and improvements that correspond to current needs and preferences. Mass-tailored refurbishment concepts based on typical homes could help to increase accessibility and individuality of flats and ease life in cramped conditions.

Therefore, this paper suggests that cohort creation may be extended to apartment layouts, thus adapting to multiple scales. The study tests the idea with the 1960–80s cohort of Finnish apartment blocks. In Finland, this vintage is of high importance due to its sheer size: it accounts for 40% of all Finnish homes (Hassler, 2009). The physical repair need in this part of the stock has been acknowledged (e.g. Lehtinen, Nippala, Jaakkonen & Nuuttila, 2005). Some attention has also been paid to the significance of changing demographics, mainly the ageing of population (e.g. Lankinen, 1998; Sorri, 2006) and increasing multiculturalism (e.g. Dhalmann, 2011; Maununaho, 2012). Although the layouts of the buildings and flats are factually non-standardized, the stock is nevertheless considered to be monotonous (Hytönen & Seppänen, 2009, p.116). Therefore, the hypothesis is that the flat design is also repetitive, at least to some extent. The motivation for the research work is in utilizing the repetitive nature of the stock in conceptualizing how these homes could respond to the ever-growing individualization requirements for housing. This paper creates the basis for later work that is to encompass the needs of the elderly as well as those of larger households.

BACKGROUND

Typological approaches

Geometry-based taxonomies, such as typology, morphology and typomorphology, are established methodologies for the systematization of architectural knowledge. They stand for the study and classification of built forms. Typology usually refers to buildings; typomorphology is associated with urban forms; and morphology appears in both contexts. Madrazo (1995) and Krokfors (2006) have performed extensive literature reviews on the history of types and typology in architectural theory. The term 'type' has had several definitions within the discipline (Madrazo, 1995; Krokfors, 2006). Although the term did not emerge until early 19th century, the idea of types has been embedded to architectural theory since Vitruvius. In the 1960–70s, typology drew the attention of theorists such as Giulio Carlo Argan and Aldo Rossi, among others. (Madrazo, 1995). According to Argan, the type is a principle that allows variation. Types are not fixed a priori but deducted from a series of cases. Therefore, the creation of a type depends on the existence of similar instances, and a type result from confronting and fusing all of them. (Argan, 1963). Rossi considered typology as the means to construct a scientific basis for architecture (Madrazo, 1995).

More recently, for example Francescato (1994) and Lawrence (1994) have discussed typology as a means of scientific investigation. Although typology is usually employed to examine the existing stock, it can also be employed for developing new buildings (e.g. van der Voordt, Vrielink & van Wegen, 1997) as suggested by Raphael Moneo (1978, as quoted in Krokfors, 2006). Typology is especially popular in historical research (e.g. Caniggia & Maffei, 2001; Vissilia, 2009; Mashadi, 2012), but Ju, Lee and Jeon (2014) have studied the typologies of plans in contemporary Malaysian apartment buildings and flats. Since the 1980s, graph theory (Steadman, 1983; Roth and Hashimshony, 1988) and computer-aided analysis methods have provided new tools for typological research.

Research on Finnish vintage cohorts

In Finland, work with vintage cohorts began in 1985, when a vast research project was initiated to create material for renovation education. The research focused on load-bearing frames, structures, and HVAC systems of blocks of flats from 1880 to 2000; the first results of this study were published in 1990 and the last in 2006. The study divided the housing stock into four cohorts: 1880–1940 (Neuvonen, Mäkiö & Malinen, 2002); 1940–60 (Mäkiö et al., 1990); 1960–75 (Mäkiö et al., 1994); and 1975–2000 (Neuvonen, 2006). Of these, the last two are of interest for the current study. The 1960–80s residential cohort has also been thoroughly studied regarding its durability properties, deterioration of structures and repair needs (e.g. Lehtinen et al., 2005; Lahdensivu, 2012; Lahdensivu, Mäkelä & Pirinen, 2013a; Lahdensivu, Mäkelä & Pirinen, 2013b) and energy performance (e.g. Linne, 2012; Uotila, 2012; Lahdensivu, Boström & Uotila, 2013).

1960–70s cohort: technical properties

All the aforementioned publications concentrate on the technical properties of the vintages. During 1960s and 1970s, four basic structural systems were used: brick walls; concrete columns; concrete walls; and concrete crosswalls. With a 60% share, the most common was the concrete crosswall frame, which could be cast in situ or prefabricated partially or fully. The facades were usually prefabricated three-layer sandwich panels. Both strip panels and room-size square panels were used, but the latter were more usual. (Mäkiö et al., 1994, p.53–55). Until mid-1970s, slabs were most often in situ cast. After 1975, prefabricated hollow-core slabs started to take over (Mäkiö et al., 1994, p.71–74). Connections, tolerances, and a modular arrangement were standardized in 1969 and taken into use during the 1970s (Hytönen & Seppänen 2009, p.96–98). Practically all buildings were equipped with central heating (district heating or an oil boiler) at that time (Mäkiö et al., 1994, p.214). The ventilation was natural or mechanical exhaust ventilation, typically with shared ducts (Mäkiö et al., 1994, p.220). As the construction techniques and the HVAC systems of the era are already covered well, they have been left outside the scope of the current study. However, the present literature provides only little insight into apartment layouts.

1960–70s cohort: plan design

Regrettably, existing studies that focus on adaptation of flats or refer to typical buildings fail to utilize large enough samples to have potential for generalization. Mäkiö et al. (1994, pp.166–176) present plan drawings for 43 landings with 138 flats from 1960 to 1974. These are described as 'examples of apartment blocks' that 'represent the annual amount of construction and the frequency of frame and façade types in different years.' Examining the plans, one could argue that rather the aim might have been to include many different layouts. Also Pärnänen, Vaarna and Kukkonen (1994) studied the renovation possibilities of apartment blocks from

1946–72. They describe their ten case study buildings and the flats in those as 'the most common' and 'the most typical,' without presenting any evidence for the claim (Pärnänen et al.,1994, p.3).

In the 2000s, the suitability of blocks of flats from 1950–80s was examined for housing senior citizens (Sorri, 2006). This study utilized ten buildings, which were selected for 'representing the cohorts as well as possible' (Sorri, 2006, p.25). Although the accessibility problems of the flats are evaluated, the report does not present any layouts. Even more recently, two publications by the Finnish Association of Civil Engineers promoted nine apartment blocks with 248 flats to 'model buildings.' They are stated to be typical representatives of 1970s construction in terms of the type and extent of serial production and the responsible construction company (Rantala, 2008, 2009). Once again, no statistical basis for these claims is presented. The aforementioned studies seem to have based their selection of typical cases on educated guesses. Obvious benefits for generalizability could have been achieved by investigating the typical layouts with data. This paper bridges this gap in knowledge.

Influence of design guidance

Although the plans have not been studied systematically before this paper, erstwhile design guidance can provide some insight into the plan design. Construction was guided by binding norms and instructional guidelines (Mäkiö et al., 1994, p.240). The norms set the minimums for flat size (20m²), room size (7m²), room height (2.5m) and floor height (2.8m) (Mäkiö et al., 1994, p.242). In practice, room heights were 2.5–2.6m because intermediate floor structures were 200–300mm thick (Mäkiö et al., 1994, p.71–74).

Flat distribution was guided by the Tax Relief Act of 1962. To receive the tax relief, none of the flats could exceed 120m² and the number of small flats (<50m²) could not exceed one-third. (Mäkiö et al., 1994, p.255). The areas of flats were guided by the guidelines for publicly subsidized blocks as Table 1 shows. These guidelines also provided instructions for the width of the living room and hall. The former was to be at least 3.3m (–1970) or 3.6m wide (1970–), and the latter at least 1.5m wide. The minimum room area was set at 10m² but no other guidelines were given on the dimensions of other rooms. (Mäkiö et al., 1994, p.194).

In 1968, the Finnish National Housing Board recommended using prefabricated building parts in publicly financed housing. In practice, the recommendation led to the standardization of dimensions and products in privately financed construction as well (Korpivaara-Hagman, 1984; Keiski, 1998). Furthermore, Mäkiö et al. (1994) state that the difference between publicly and privately financed flats is mainly in the materials used in interior finishing, as opposed to, for example, layouts and dimensions.

Besides the guidelines provided by officials, good construction practices have been promoted in the RT Building Information File since 1943. The RT File, which is still updated and widely used, was founded by the Finnish Association of Architects for post-war reconstruction. It has been published by a non-profit foundation since 1972. (Mäkiö et al., 1994, p.278). At that time, the File provided space requirements for furniture and equipment in living rooms, bedrooms, kitchens and bathrooms (RT 930.10 ... RT 930.50), but instructional layouts were given only for bedrooms (RT 935.50; 50 configurations) and bathrooms (RT 936.50; 26 configurations).

Table 1. Recommended areas for publicly subsidized flats (Mäkiö et al., 1994, p.194).

Number of rooms	Recommended area (m^2)
1	30–35
2	45–65
3	65–80
4	80–100
5	100–120

Influence of societal conditions

As shown above, design guidance did not restrict plan design notably. The erstwhile societal conditions may act as another explanatory factor. Finland industrialized and urbanized much later and, as a consequence, more rapidly than most European countries. In the beginning of 1950s, 70% of the Finnish population still lived in rural settings, but the economic structure was changing drastically. The significance of agriculture as the means of livelihood diminished while industries and services were growing rapidly. Simultaneously, large generations born right after WWII were becoming independent and entering the working life. This resulted in an unprecedented wave of migration to cities between 1969–75, later titled 'the Great Migration'. (Laakso & Loikkanen, 2004, pp.23–25).

As a result, quantitative goals replaced qualitative ones in housing production. In order to solve the housing shortage, developers were given control over the design and manufacture of buildings and entire neighbourhoods. Architects lost their influence on housing design. The new prefabricated construction technology dictated much of the flat layouts, such as room spans, and favoured straightforward, no-nonsense plans. Although the introduction of long-spanning hollow-core slabs freed flats from load-bearing interior walls in the 1970s, that was not considered as a major change for architects' working conditions. (Mäkiö et al., 1994, pp.177–180). Few parties controlled construction: in late 1970s, only 15 manufacturers were responsible for producing 75% of all panels. Critique for anonymous mass housing, which had begun around 1970, increased towards the end of the decade and started to have cash-flow consequences for the concrete industry. In late 1970s, the industry re-engaged with architects to respond to the call for individuality. Consequently, the 1980s denoted developments in concrete construction. In early 1980s, this work focused largely on facades. (Hytönen & Seppänen, 2009, pp.114–116,137–139,177–183). At the same time, the scale of neighbourhoods started to decrease and the variation of building volumes and types to increase. The postmodern architecture of late 1980s was the peak of this development. In early 1990s, an economic recess resulted again in increased building size and decreased individuality. (Neuvonen, 2006, pp.213–220).

RESEARCH MATERIAL AND METHODS

The primary research material for the current study was gathered from the archives of the Housing Finance and Development Centre of Finland (ARA), the government agency for funding public housing. The material consists of architectural drawings that were used for applying for state-supported construction loans. These are sets of general arrangement drawings i.e. floor plans, site plans, elevations, and sections. The sample consists of 320 drawing sets picked from 51 cities. The material covers 8745 flats, which corresponds to 4.4% of the stock. The sample size was guided by the sample size Mäkiö et al. (1994) used for studying structures (260 buildings). With regard to plans, the sample is 35-fold to the largest sample in preceding research (Rantala 2008 & 2009: 248 flats). All the material was analyzed, although it reached saturation i.e. a state in which 'no new or relevant data seem to emerge regarding a category' (Strauss & Corbin, 1990, p.188) early on.

The majority of the selected buildings, 260 blocks of flats, are located in 43 neighbourhoods in 15 cities participating in ARA's Development Programme for Residential Areas in 2013–

2015. These districts were chosen to the programme by the host cities. Buildings were picked from each district with suitable candidates to maximize geographical and annual coverage for 1968–1985 (emphasizing the 1970s). 1968 was chosen for being the year the Finnish National Housing Board first required using prefabricated building components when financially advantageous (Korpivaara-Hagman, 1984). 1985 marked the end of the national housing programme for 1976–85 and was also the year a new law for improving the state of housing was given, including increased attention for inhabitant participation (Asuntohallitus, 1984, pp. 35–36; Valtion asuntorahasto, 1999, p.17). These years are the years the projects were granted loans. This not only makes analyzing the information easier by eliminating the need to research dates of completion, but also improves the accuracy of the results for the purposes of this study: every building represents the erstwhile design practices regardless of the time taken by the construction.

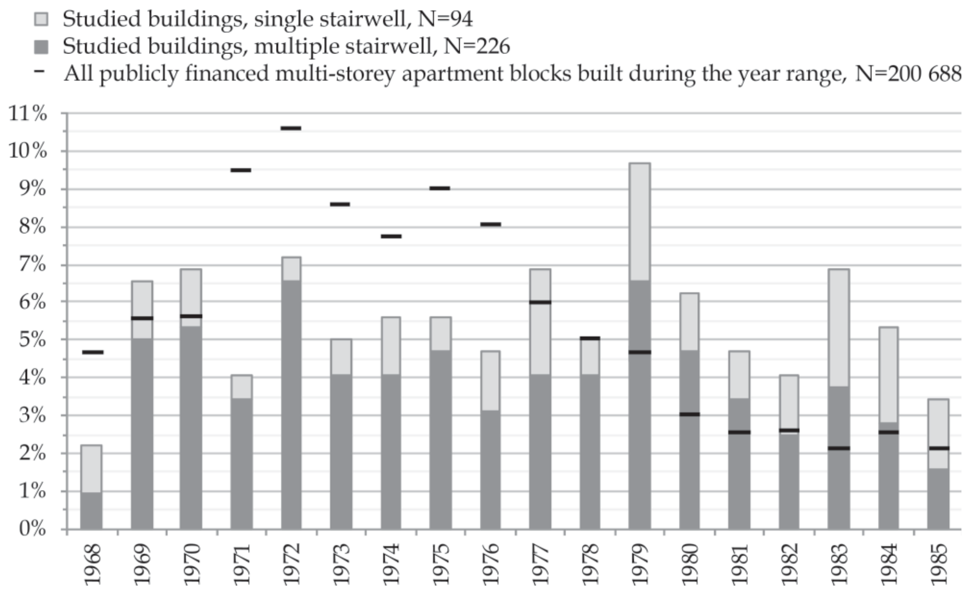

Figure 1. Distribution of studied buildings and all public-funded apartment buildings within the chosen year range. Sources: Authors' research; Kakko, 2011; Laine, 1993.

An effort was made to roughly balance the building type distribution to slab blocks and tower blocks by using a ratio of 3:1 (see Figure 1). Based on a comparison sample (N=1125) acquired from ARA's Register of Real Estate (2013), tower blocks were slightly overrepresented among the studied buildings compared to all contemporary publicly funded production with their portions being 29.4% and 24.3% respectively. As some flat types are noticeably more common in either slab or tower blocks, this has a slight effect when considering their prevalence in a wider context.

Other characteristics, such as tenure type, targeted demographic (students, elderly or disabled people etc.), number of floors, or possible later renovations were not considered. Although the sample was not picked totally randomly, the selection was random from the viewpoint of the subject of study, i.e. flat types and distribution. There is no reason to believe that these factors would have affected the selection of the neighbourhoods for the Development Programme.

Additionally, floor plans for 216 flats – three per each year and room count used in this study – were gathered from the Finnish housing and property sales website Etuovi.com (2014) in order to perform a comparison between different tenure types. The sample contains both publicly and privately financed owner-occupied apartments. To further investigate the generalizability of the research material and the applicability of the types, comparisons were made to ARA's Register of Real Estate (ARA, 2013), official statistics of Finland (OSF, 2007; 2013) and statistics presented in literature (Laine, 1993; Kakko, 2011). For each of these, the samples contained all comparable dwellings for which the relevant data was available.

Defining the flat types

The method is a simple application of graph theory (see e.g. Roth & Hashimshony, 1988). To simplify the process, only one floor plan for each building was studied when determining the flat types. In the vast majority of cases, all residential floors had identical layouts. If the ground floor plan differed from the rest, the distinction tended to be absence of some flats in favour of common areas, not differing flat layouts. Therefore, the results obtained using this method can be considered representative of the general flat type range within the studied material. Using a graphics program, flats with different room counts were first highlighted in floor plans as Figure 2 shows. Next, the plans of the flats were turned into line-weighed, colour-coded graphs with transparent backgrounds. The graphs were piled on top of each other to identify recurring room layouts as seen in Figure 3. This examination was repeated until the remaining flats were too dissimilar to form any more distinctive types. The consideration of structural elements was limited to load-bearing and non-load-bearing walls. The walls between flats are load-bearing with virtually no exceptions, but inside the unit, the structure can vary more. The most common situation is pictured and possible variation noted in text. The dimensions and door and window locations later shown in the plans of the flat types are mean values determined visually from the piled graphs.

Figure 2. A building plan with flats of different room counts highlighted with simple graphs. N.B. Kitchens and kitchenettes do not count as rooms.

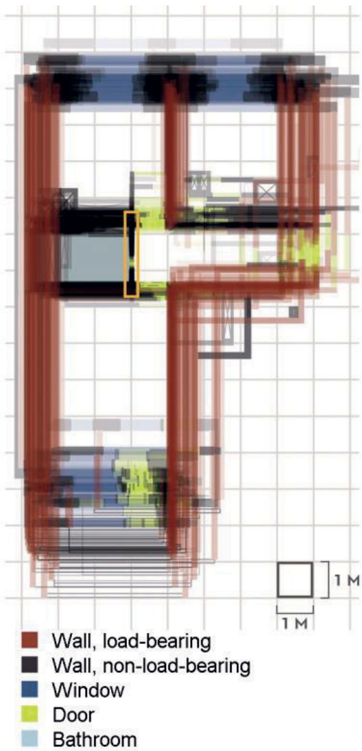

Figure 3. A pile of colour-coded graphs for flat type 2-1A. Line weights and colours distinguish different elements of the plan. In the image, the graphs have been aligned along the bathroom wall circled with orange.

Flat types were only defined for apartments with four or fewer habitable rooms. The proportion of these flats is 99.9% in the research material and 99.7% in a sample of 163 530 public-financed rental flats from the corresponding years (ARA, 2013).

According to Laine (1993), even though owner-occupied flats are on average larger than rental flats, their predominant type still has only three rooms. Additionally, based on the research material, variation in flat layouts increases with room count, which decreases the applicability of typology, even if types could still be defined.

Renovation possibilities were a major consideration in grouping the flat layouts. This led to a hierarchical categorization tree in which flats are sorted based on various qualities that affect the feasibility and cost of renovations. The primary categorization criterion was the number of habitable rooms, i.e. excluding the kitchen, bathroom, hall, walk-in closets etc. Based on the research material and considering the most common building frame systems of the time, most habitable rooms are surrounded by at least three walls that are either load-bearing or exterior walls (Mäkiö et al., 1994). As the rooms themselves are of fairly standard sizes, the amount of space – and the way it is partitioned – is mainly a function of the room number.

The secondary categorization criterion was the general room layout. Due to the aforementioned prevalence of load-bearing walls, the sizes and locations of most rooms are rather fixed, barring extensive structural work. This step considered the location of all habitable rooms as a whole, allowing variation in the placement of functions.

The tertiary categorization criterion was the location of the bathroom. Since the bathroom usually determines the location of vertical drainpipes, it has a major effect on the feasibility and cost of changing the room layout during renovation. Changes to the bathroom floor – altering the layout, enlarging the room or making a new one – also often affect the flat below due to horizontal drains running inside the floor, which emphasizes the importance of the room in single-flat renovations. Possible separate toilets were not considered when one was also present in the bathroom. Based on the above criteria, the recognized flat types are identified with a tag 'X–YA' in which

- 'X' is the amount of habitable rooms in the flat, the primary categorization criterion.
- 'Y' is an identifier for the flat's main type, based on the secondary categorization criterion.
- 'A' identifies the subtype of the flat when applicable, based on the tertiary categorization criterion.

THE TYPOLOGY OF FLATS

Using the criteria defined above, ten distinct main types were identified and further divided into eighteen subtypes. These are listed in Table 2, along with figures on their distribution. Overall, the flat types cover 80.4% of all flats in the studied buildings. Their proportion of all flats in the sample correlates somewhat with the proportion of flats with different room counts: the more prevalent the flat size, the greater the proportion of recognized flat types within it. This could indicate higher proportion of standardized plans within rental flat production, in which two-room units are especially common (ARA, 2013; Laine, 1993). However, due to the sample size and not knowing the tenure types of the studied buildings, causation cannot be stated. It is also likely that the drop in the proportion of recognized flat types from three- to four-room units would be less severe with a larger sample size: there were four-room flats that were very similar to the smaller types but not numerous enough to justify defining a type. As Table 2 shows, each main type has a subtype that is significantly more common than the others. Additionally, each room count has a clearly dominant flat type, the '–1A.'

Table 2. Distribution of different flat types within research material. * Excluding special housing that in the studied drawings was specifically marked as being designed for students, disabled people, or the elderly.

Flat type	Distribution of recognized flat types within same room count			
	Slab & tower blocks combined	**Slab blocks**	**Tower blocks**	**Excluding special housing***
1-1A	56.4%	61.8%	43.4%	61.1%
1-1B	14.7%	8.8%	28.8%	14.2%
1-2	5.8%	8.3%	0.0%	5.4%
All 1 room flat types	76.9%	78.9%	72.3%	80.7%
Other 1 room flats	23.1%	21.2%	27.7%	19.3%
2-1A	35.0%	46.6%	5.5%	37.2%
2-1B	2.1%	2.9%	0.0%	2.3%
2-1C	4.4%	5.7%	1.1%	4.0%
2-2	21.6%	6.7%	59.3%	23.0%
2-3A	12.5%	16.1%	3.5%	11.1%
2-3B	6.5%	6.3%	7.1%	5.7%
2-3C	2.0%	2.3%	1.1%	1.8%
All 2 room flat types	84.0%	86.6%	77.5%	85.2%
Other 2 room flats	16.0%	13.4%	22.5%	14.8%
3-1A	40.2%	57.3%	2.9%	39.5%
3-1B	6.8%	9.9%	0.0%	6.9%
3-1C	6.0%	8.7%	0.0%	6.4%
3-2	23.7%	3.0%	70.6%	25.5%
3-3	5.4%	7.5%	0.8%	5.5%
All 3 room flat types	82.0%	85.4%	74.2%	83.9%
Other 3 room flats	18.0%	14.7%	25.8%	16.1%
4-1A	34.9%	39.7%	9.7%	34.0%
4-1B	14.1%	16.7%	0.0%	15.0%
4-2	4.6%	0.5%	26.4%	4.9%
All 4 room flat types	53.6%	53.6%	36.1%	54.0%
Other 4 room flats	46.4%	43.1%	63.9%	46.0%
All flat types	80.4%	82.8%	74.2%	82.2%
Other flats, 1–4 room	19.5%	17.2%	25.8%	17.8%
>4 room flats in Sample	0.1%	0.2%	0.0%	0.1%

One-room flats

Figure 4 presents one-room flat types. Type 1–1 is overwhelmingly the most common, covering 71.1% of all one-room flats. The share of 1–2 is 5.8%. As could be expected due to their small size, the flats do not vary much in shape or layout. Deviation from a square plan usually occurs as elongation along the façade. All the studied flats – within the research material and the various comparison samples – have only one wall with windows and are located centrally on their landing.

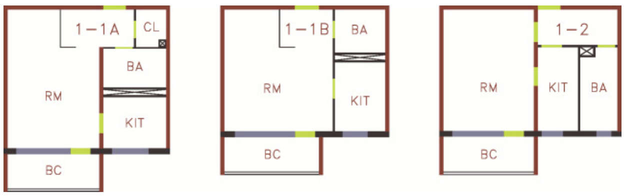

Figure 4. One-room flat types.

Main type 1–1

Main type 1–1 appears in both slab and tower blocks with subtype A being more common in slab blocks and B being more common in tower blocks. In slab blocks they are generally between types 2–1 and 3–1, in tower blocks between 2–2 and 2–2.

Subtype 1–1A

The most common one-room flat type consists of a single main room next to which are the kitchenette, the bathroom and sometimes a walk-in closet. The wall bisecting the flat is load-bearing slightly more often than not. How far it extends beyond the sides of the bathroom varies: sometimes the kitchenette is completely open to the room or the hall lies behind the wall in the corner of the flat, displacing the closet, though especially the latter is rare. The dimensions of the duct between the bathroom and kitchenette vary, but an oblong shape is the most common.

Subtype 1–1B

The different hall location of subtype B means the routes inside the flat are slightly more straightforward than in subtype A. In this flat type the wall bisecting the unit is very rarely load-bearing. Open kitchenettes are also more common than in subtype A, though still rarer than closed versions.

Main type 1–2

Unlike 1–1, main type 1–2 only appears in slab blocks. The routes between the rooms are the same as in 1–1, with the addition of a door between the kitchen(ette) and the hall, although the actual layout differs significantly. Because the kitchen(ette) and bathroom are next to each other along the façade and the hall is squished behind them, all rooms except the main one tend to be long and narrow. The wall separating the main room is always load-bearing, although it does not always extend all the way to the back wall.

Two-room flats

Two-room flats, being the most common room count in the research material, also have the highest number of definable types (see Figure 5). Likely related to this, they also have the highest percentage of flat type coverage: 84.0%. 2–1 is the most common by far, covering 41.4% of all two-room flats, with 2–2 and 2–3 following behind with 21.6% and 21.0% respectively. Unlike one-room units, two-room main types are rather clearly divided between building types. Each main type has its distinctive shape stemming from its location in relation to the building and stairwell.

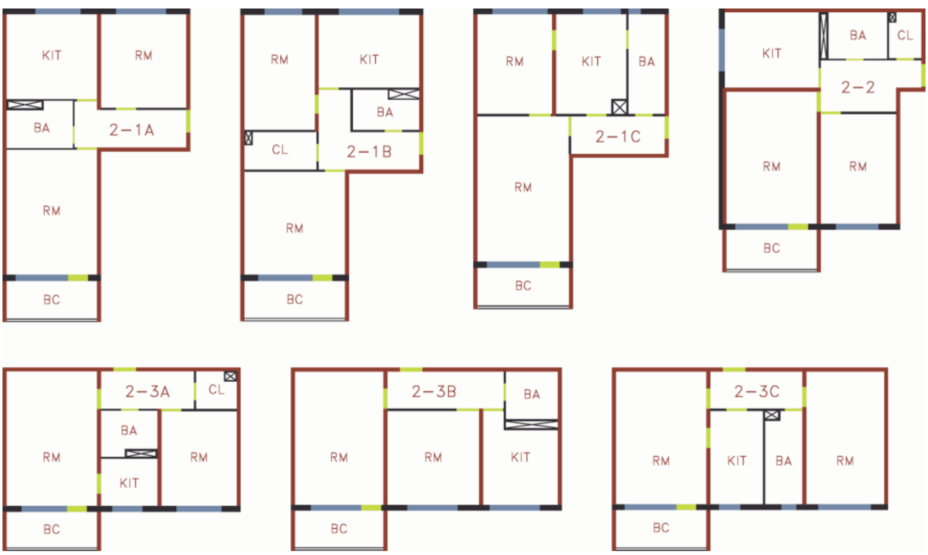

Figure 5. Two-room flat types.

Main type 2–1

The most common two-room main type generally appears in slab blocks. It spans across the building and is usually located opposite to an identical flat with a one-room flat in-between or next to a single type 3–1 flat. All the flats in the main type only open in two directions, regardless of their position in the building. Inside the flats, the rooms are mainly located based on their need for a window, which places the habitable rooms next to façades with the hall, bathroom, and possible walk-in closet in the middle. As is logical from a technical standpoint, kitchens and bathrooms usually lie next to each other. The size and shape of their shared duct varies, as does the room it is located in. The living room is usually across the hall from the kitchen.

Subtype 2–1A

The most common subtype, 2–1A, covers 84.4% of all flats of its main type. In 43.3% of the flats, there is also a walk-in closet next to the bathroom. These tend to have a wider, more irregularly-shaped hall. In a minority of cases, the bedroom is accessed through the adjacent kitchen or living room. The width of the flat varies in both horizontal directions. The only partition wall that may be load-bearing – and usually is – is between the two adjacent habitable rooms.

Subtype 2–1B

This subtype only appears in slab blocks and is rare even there. The exact line of division between the hall and kitchen varies, with the short hallway next to the bathroom being part of one or the other. When the hallway belongs to the kitchen, there is either no walk-in closet or it is smaller to allow access to the room in the corner from the hall or the adjacent room. In this subtype, the partition wall perpendicular to the façade appears always to be load-bearing, although the number of studied flats is significantly smaller than for 2–1A.

Subtype 2–1C

In this type, all rooms – including the bathroom – are along façades. Therefore, the overall shape tends to be longer in that direction in comparison to the previous subtypes. In roughly half of the flats of this type, the bathroom has a separate toilet at the end, next to the hall with a door in-between. None of the flats have walk-in closets. The partition wall between the kitchen and adjacent bedroom is always load-bearing; for the one next to the bathroom there appears to be an even split.

Main type 2–2

This main type appears almost exclusively in tower blocks, covering 59.3% of two-room units. The few slab blocks it is found in usually differ considerably from the ordinary rectangular shape. In the research material, this flat is most often located in two adjacent corners of a tower block with a one-room unit in between and a pair of type 3–2 flats in the remaining corners. With the same overall layout, two general shapes for the flat were found: the square one shown in Figure 5 and a more oblong variation that is slightly stretched horizontally but still otherwise similar, with the possible exception that the living room is accessed through the kitchen. In most cases, however, all the rooms are accessed through a centrally located hall. The shape of the hall varies, depending mainly on whether there is a walk-in closet in the corner or just an entrance and an extension to the hall area. As usual, the main vertical duct is located between the kitchen and bathroom, varying in size and shape but usually spanning at least two thirds of the length of the wall. The location of the load-bearing walls varies more than in other flat types, except the related main types 3–2 and 4–2. As a general rule, they are parallel to load-bearing exterior walls. The walls within the flat that surround the bathroom and the possible walk-in closet are never load-bearing.

Main type 2–3

The main type 2–3 appear mostly in slab blocks, although not exclusively. Again, exceptions usually occur in tower blocks differing from the standard square shape. The usual location is similar to one-room units: in the middle of the façade, never in a corner. In slab blocks, this generally means that the flat is between two type 2–1 units. Like one-room flats, these units never have windows on more walls than the one shown in Figure 5. Since the type only has one façade wall, all rooms requiring a window are arranged in a row along it with the hall behind them. In most cases, at least one of the walls between these rooms is load-bearing.

Subtype 2–3A

For the most part, this subtype appears in slab blocks and often in buildings that also have type 1–1A flats. The similarities between these flat types are obvious with the main difference being the addition of a room. This subtype is by far the most common in its main type, covering 59.5%. The most notable variation of layout is the existence of the walk-in closet in the corner. If the closet is absent, the adjacent room usually extends to the rear wall. In a clear minority of cases, the kitchen has a door on both sides. As in the flat type 1–1A, the duct between the kitchenette and bathroom is usually long and narrow, often spanning the width of the whole wall. What little variation there is in the flat's external dimensions occurs perpendicular to the façade.

Subtype 2–3B

This subtype appears roughly equally in slab blocks and tower blocks. It differs from the other 2–3 flats by not having a one-room counterpart and by having a full kitchen. The kitchen can be located next to the bathroom or in the middle. Compared to the other 2–3 subtypes, the dimensions and shape of the rooms vary rather considerably. Either both the partition walls perpendicular to the façade are load-bearing or neither of them is. Both options are equally common. The overall dimensions and the shape of the units also vary more than in most flat types.

Subtype 2–3C

The rarest of all the defined two-room flat types is a straight expansion of the one-room flat type 1–2. Therefore, nearly all the statements made about 1–2 apply here, as the extra room is simply added to the side with a door or a doorway to the hall. One exception is that, unlike any of the 1–2 flats, some of the units in this subtype have non-load-bearing internal crosswalls instead of load-bearing ones. Variation in the size and the shape of the units is nearly nonexistent.

Three-room flats

Three-room flats are the second most common room count in the research material and the comparison sample from ARA's Register of Real Estate (2013). Though considerably fewer in total number than two-room units, their flat type coverage is almost as high: 82.0%. Figure 6 presents the types. The distribution of the flat types is similar to the two-room counterparts with 3–1 at 53.0%, 3–2 at 23.7% and 3–3 at 5.4%. All the flat types are clear and mostly direct continuations of their two-room counterparts, with no noticeable difference aside from the added room. The routes inside the flats rely on a central hall through which all the rooms are accessed. Structural principles also remain unchanged with the added room usually being behind a load-bearing wall.

Figure 6. Three-room flat types.

Main type 3–1

Main type 3–1 is found almost exclusively in slab blocks. It usually appears with types 2–1 and 1–1 or paired with an identical unit. Like type 2–1, 3–1 also spans across the building with the kitchen and habitable rooms next to the façades.

The kitchen and the bedroom are usually located next to each other with the living room on the opposite side. No difference in the room size was noticed between the corresponding subtypes of the main types 3–1 and 2–1. The flat only opens in two directions, with few minor exceptions when located at the end of a building.

Subtype 3–1A

This most common subtype has a fairly similar share of all the flat types in its size group as the corresponding smaller type, 2–1A. As for the layout, everything observed about the type 2–1A also applies, with the obvious addition of one bedroom. This bedroom also often has its own walk-in closet, especially if there is not one next to the bathroom. The partition wall next to the added bedroom and perpendicular to the façade is usually load-bearing.

Subtype 3–1B

As with the above subtype, the only difference in layout between this and the smaller type 2–1B is the added bedroom behind a load-bearing wall. Unlike the subtype A, however, this flat type was found to be significantly more common than its two-room counterpart.

Subtype 3–1C

In this subtype too, the basic layout is similar to its smaller counterpart, the 2–1C. The hall appears usually to be somewhat larger, but due to the rareness of the type in the sample, this may be coincidental. With the same caveat, all the rooms of this flat type – unlike those of 2–1C – are directly connected to the hall.

Main type 3–2

Like type 2–2, type 3–2 also appears almost exclusively in tower blocks with the exceptions being the slab blocks whose shape is not the usual rectangle. These flats are normally located in two adjacent corners. Like its two-room counterpart, 3–2 occurs in two main shapes: the square one and a more oblong variation. There is no noticeable difference to the flat type 2–2 in the layout, room sizes, connections, or structural elements, aside from the added bedroom.

Main type 3–3

Type 3–3 appears virtually exclusively in slab blocks. It is usually paired with a mirrored identical flat and either two type 1–1 flats or one 2–3 flat in-between them, along the balcony façade. Similarly to its closest relatives 2–1 and 3–1, type 3–3 also opens in two directions and is arranged around a central hall. Structural elements are no different from the type 2–1 aside from the added room, which is, again, usually behind a load-bearing partition wall. The main distinction to 3–1 is the location the additional room, which results in a longer hall but does not otherwise change the layout or the connections.

Four-room flats

Four-room flats are relatively rare in the sample – and the contemporary flat production in general – which presumably is the reason for not identifying many types for them. Figure 7 shows the recognized types. Like its smaller counterparts, the main type 4–1 covers a clear majority of all flats in its size group: 49.0%. The other main type, 4–2, is clearly behind at 4.6%. Among these flats, precise layouts and room dimensions appear to be less consistent than in smaller units. Especially locations of walk-in closets and secondary toilets vary considerably. As before, all types are clear continuations of their smaller counterparts.

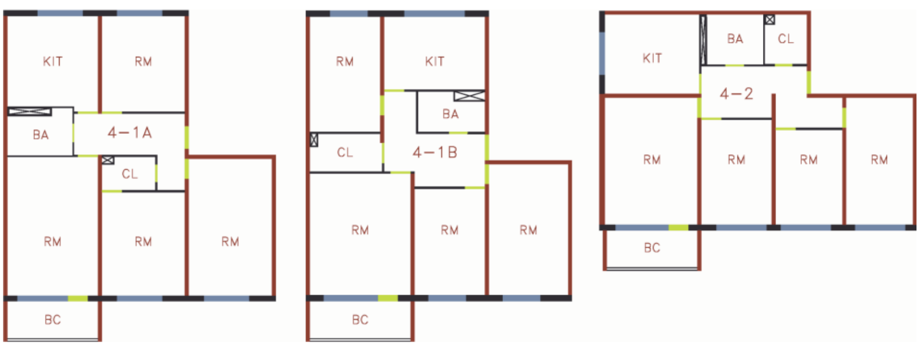

Figure 7. Four-room flat types.

Main type 4–1

Like all the first main types (X–1), 4–1 also occurs mostly in slab blocks. All exceptions to this rule are of the subtype 4–1B. Both subtypes are usually paired with the type 3–1 across the stairwell. With the exception of the added room, all general statements made about the main types 2–1 and 3–1 also apply here.

Subtype 4–1A

As with 3–1A, the only difference to the smaller related flat type is the added bedroom, usually with no walk-in closet. Individual rooms, connections between them and structural elements generally remain unchanged.

Subtype 4–1B

Everything stated about the subtype 4–1A also applies here. Due to the rareness of the subtype in the already small sample of four-room flats, it is possible that more differences to the smaller flats – such as the number of walk-in closets – could have been observed if the sample had been larger. These kinds of differences, however, are rather insignificant from the perspective of renovation, since they always encompass non-load-bearing structures.

Main type 4–2

Even more than its two- and three-room counterparts, the 4–2 appears virtually exclusively in tower blocks. In the buildings of the research material, there was ever only one 4–2 flat per floor. The layout and connections in 4–2 are similar to its smaller counterpart, as are the load-bearing elements and the dimensions of individual rooms (aside from the hall).

Flats outside the defined types

Many of the units that remain outside the defined types are clear variations of those. For example, the first and third layout in Figure 8 are very close to 2–1B and 1–1A, respectively. The same appears to be true for flats with five or more rooms, although these are extremely rare. Individual rooms are also similar in shape and size to those of the recognized flat types. Since room sizes are, to a large degree, determined by the frame system used, this could be expected.

Figure 8. Examples of flats outside the defined types.

DISCUSSION

Representativeness of the flat types regarding the Finnish housing stock

The dominating factor in determining the usefulness of the types is how much of the whole building stock they encompass. Though few in number, the existing applicable works using the concept of typical buildings seem to comply with the flat types defined in this study. Within the chosen year range, Mäkiö et al. (1994) present 15 landings, Pärnänen et al. (1994) two buildings and Rantala (2008; 2009) eight buildings. Table 3 shows the occurrence of the types in them. As in the current study, for each room count, the most common type was the X–1.

Table 3. Occurrence of recognized flat types in the buildings of previous studies.

Publication	Buildings or landings	All flats	Recognized flat types, % of all	Types exhibited
Mäkiö et al. (1994)	15	138	60.5%	11
Pärnänen et al. (1994)	2	33	81.8%	4
Rantala (2008; 2009)	10	248	100.0%	10

In addition, the research material was compared to a sample of flats for sale on Etuovi.com (2014). Table 4 presents the coverages of types for the research material and the comparison sample. The biggest difference appears with the largest flats. This could be expected, since those flats also exhibited the most variance within the research material and obviously have the highest potential for different layouts. Nonetheless, the flat type coverage among different room counts is consistent between the samples: the percentage is highest for two-room flats and decreases for other room counts in the same order. This is also true when considering the coverages of the most common flat types – which are the same in both samples – of all units with equal room count.

Table 4. Occurrence of recognized flat types in random owner-occupied apartments from the years 1968-1985, N=216, and research material, N=8745. Sources: Authors' Research; Etuovi.com, 2014.

Flat room count	Most common flat type		Portion of recognized flat types		Portion of most common flat type	
	Comparison sample	Research material	Comparison sample	Research material	Comparison sample	Research material
1 room	1-1A	1-1A	70.4%	76.9%	59.3%	56.4%
2 room	2-1A	2-1A	81.5%	84.0%	27.8%	35.0%
3 room	3-1A	3-1A	70.4%	82.0%	33.3%	40.2%
4 room	4-1A	4-1A	66.7%	53.6%	35.2%	34.9%
Total			72.2%	74.1%	38.9%	41.6%

Aside from the current research and the aforementioned other studies, there is no data available on the number of specific flat layouts produced. Therefore, determining the correspondence further between the research material and all comparable construction relies on studying more general properties of the flats. This study is divided into a progression of comparison pairs, where each stage widens the context, in order to eventually evaluate the applicability of the types in the scope of all Finnish apartment blocks built during the studied period.

Correspondence between research material and all comparable publicly financed housing

To detect possible differences in the distribution of flats with different room counts, the research material – consisting of various tenure types – was compared to all the 160 210 rental flats in ARA's Register of Real Estate (2013) for which this information was recorded. The proportions of one-, two-, three- and four-room flats differed by 3.8, 1.3, 4.2 and 0.9 percentage points, respectively. One- and two-room flats were more common in the register than in the research material and vice versa. The difference is presumably due to the prevalence of smaller flats (by room count) in rental production, in which case a large sample with both tenure types should fall more closely in line with the research material. (ARA, 2013; Kakko, 2011; Laine, 1993).

To check for differences in average flat area, a random sample of 30 buildings (209 flats) was picked from the research material and compared to all public-funded flat production in the register for which the information was recorded – 355 172 flats in 12 335 buildings (ARA, 2013). The average areas were 59.9m² and 60.3m², respectively. Unlike the previous sample, this one included all tenure types, which for its part supports the assumption that the difference in room count observed above was due to a dissimilar distribution of the tenure types in the samples.

Considering the extensive regulation of publicly financed projects (Korpivaara-Hagman, 1984) – especially towards the end of the studied time period – and the similarity in flat sizes and room counts, the research material appears to be a rather accurate representation of the publicly funded flat construction of the studied era.

Correspondence between publicly and privately financed projects

In total, 41.6% of the dwellings in apartment blocks the construction of which began 1968–1985 were financed by the state. As seen in Figure 9, the exact proportion varies; state financed production peaks at 55.9% in 1971 and is 24.9% at the lowest in 1985. As shown in the background, the existing literature (Korpivaara-Hagman, 1984; Mäkiö et al., 1994; Keiski, 1998) strongly suggests that, as far as the applicability of the typology is concerned, there should be no significant differences between publicly and privately financed buildings. To shed more light on this, differences – or lack thereof – were examined in the average area and room count of publicly and privately financed flat production.

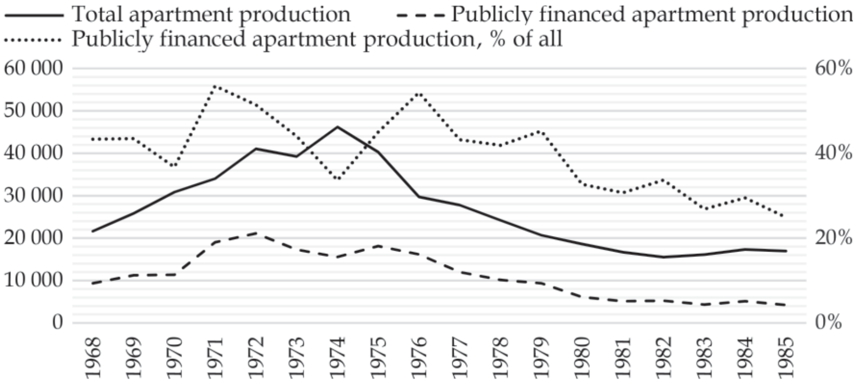

Figure 9. Finnish dwelling production in apartment blocks during the years 1968–1985. Sources: Kakko, 2011; Laine, 1993; Official Statistics of Finland, 2007.

Data on 355 172 publicly financed dwellings from ARA's Register of Real Estate (2013) was compared to statistics on privately financed dwellings built during the corresponding years. Figure 10 presents the comparison. Row houses are included in the numbers to retain comparability because they have been combined with apartment blocks in some of the sources used. Since, at least among publicly financed buildings, the different building types roughly follow the same trends in average area (ARA, 2013), the effect of including the row houses should be minimal for the current purpose. The years used in compiling the statistics vary between the sources: ARA (2013) uses the year the loan for the project was granted, Kakko (2011) and OSF (2007) use the year of completion, and Laine (1993) uses both in different tables and figures. Therefore, the numbers presented are not accurate as annual snapshots, but due to the gradualness of the change, they are usable for examining general trends.

The average area of all dwellings in these building types produced between 1968–85 differs by only 0.7m² between public and private financing, though as Figure 10 shows, this difference is not constant. It is, however, smallest in the mid-1970s, when the amount of total dwelling production in apartment blocks was at its highest. This suggests that the correspondence between publicly and privately financed projects was the greatest during the peak years.

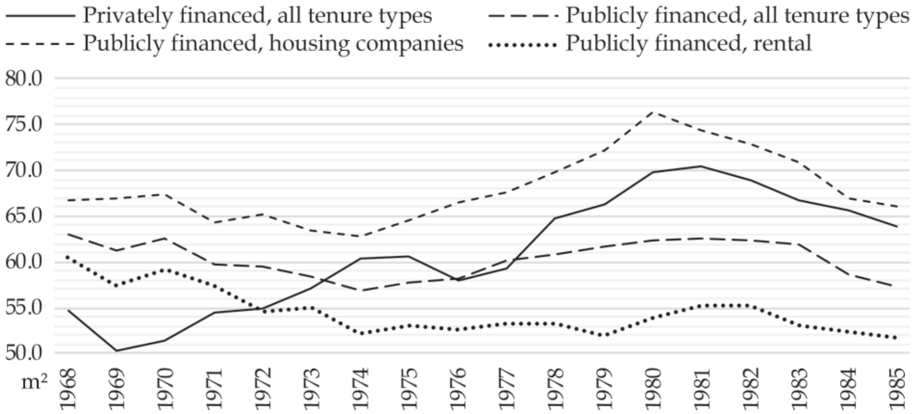

Figure 10. Average dwelling area in apartment blocks and row houses, m². Sources: ARA's Register of Real Estate, 2013; Kakko, 2011; Laine, 1993; Official Statistics of Finland, 2013.

Correspondence between rental and owner-occupied housing

Figure 10 shows that in the 1970s, the biggest difference in average dwelling area was not between financing methods but between tenure types: in publicly financed projects, the average size of owner-occupied dwellings grew, while rental dwellings initially got smaller and then stayed roughly the same. Tenure-based data is not available for privately financed dwellings, but similar figures seem likely considering the minimal difference in the average area as mentioned above and nearly identical portion of rental dwellings – 57.5% in publicly financed and 59.2% in privately financed production (Statistics Finland, 2014).

When considering the applicability of the flat types – especially from the viewpoint of generalizable renovation plans – it is important to determine whether the difference in the average area stems from a difference in average room size, which likely affects the interior configuration of a flat, or the average number of rooms. Laine (1993) states that during the 1970s, three rooms and a kitchen became the predominant type for owner-occupied flats, while most rental flats still had one or two rooms. Examining a sample of 160 210 rental dwellings in multi-storey apartment blocks from 1968–85 supports what Laine (1993) asserted about rental flats: the average room count is 2.1 (ARA, 2013).

As owner-occupied dwellings are on average larger than rental dwellings, as Figure 10 shows, the above suggests that the difference in average area could be explained with different distributions of room counts.

To examine further whether there is a difference in the average areas of flats with equal numbers of rooms but different tenure types, a random sample of 2000 owner-occupied flats (Etuovi.com, 2014) – 500 for each room count – was compared to 152 722 rental flats (ARA, 2013). A sample was also taken from the research material consisting of 90 buildings, spread evenly among the year range and containing 2545 flats in total, including both tenure types. The annual average areas of the aforementioned samples are presented in Figure 11. The average flat sizes for the whole year range were nearly identical in the samples, the largest difference occurring with four-room flats, but even this was only 2.9m². Annual variation in the average areas is minimal in the comparison samples, and even in the research material the variation appears to mainly depend on the sample size: the higher the number of flats examined, the smoother the graph.

Considering all the above, the difference in the average area does, indeed, seem to stem from rental flats generally having fewer rooms than owner-occupied flats. Therefore, the flat types as well as any refurbishment plans that are to be based on them should be fairly equally applicable to rental and owner-occupied housing.

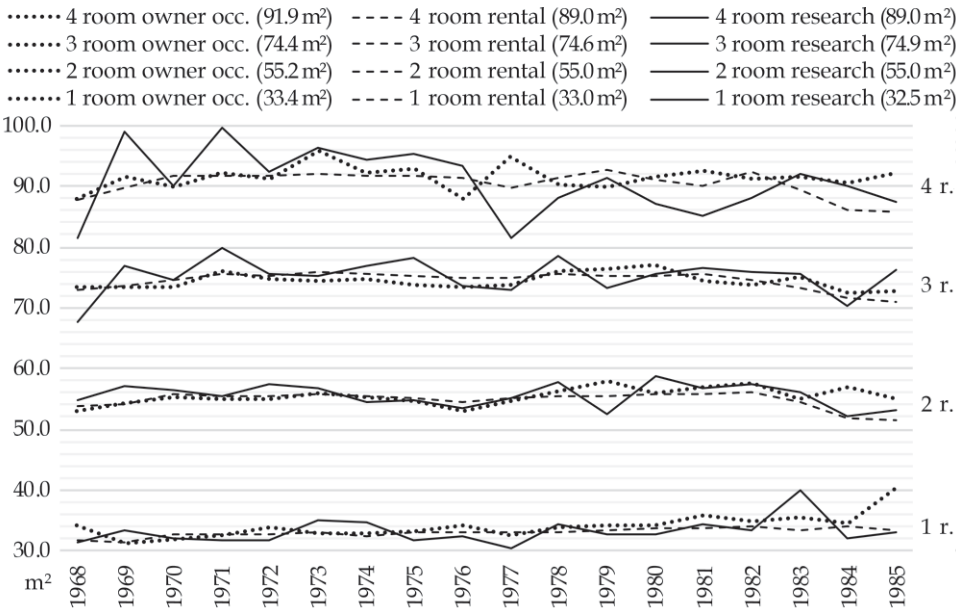

Figure 11. Average dwelling areas in privately and publicly financed owner-occupied flats, publicly financed rental flats and the flats of the research material (both tenure types), m². Sources: ARA's Register of Real Estate, 2013; Authors' Research; Etuovi.com, 2014.

Applicability of flat types to the general stock of corresponding buildings

Even if the defined types only applied to publicly financed apartment blocks – with full generalizability within that category – they would still cover 33.5% of the dwellings in apartment blocks whose construction began between the years 1968 and 1985 (Kakko, 2011; Laine, 1993). However, based on the comparisons presented above, the flat types appear equally applicable to the privately financed dwelling stock. This brings their coverage to the figures presented in Table 5 and the total number of covered dwellings to 387 884. In addition, there obviously was no immediate and complete change in housing production at either end of the studied time period. Therefore, the coverage of the flat types should well extend beyond the studied era in both directions. It is also possible that some of the flat plans were used in row houses built with the same production methods due to the similar form of the building floor.

Table 5. Percentages of flat types in different categories. Sources: Authors' research; Official Statistics of Finland, 2007; Official Statistics of Finland, 2013. Note: Percentages assume full generalizability of the sample amongst apartment blocks of the studied era.

Category	Total number of flats	Portion of recognized flat types
Apartment blocks, built years 1968–1985	482 665	80.4%
All building types, built years 1968–1985	957 208	40.5%
Apartment blocks, built 2012 or earlier	1 269 305	30.5%
All building types, built 2012 or earlier	2 865 568	13.5%

CONCLUSIONS

This study introduced the idea of forming typologies of flats from vintage cohorts to facilitate future creation of housing quality related, mass-tailored renovation and adaptation concepts. The approach was tested by applying it to one vintage, the 1960–80s, in the Finnish housing stock. The research resulted in recognizing 18 flat types, based on ten basic layouts, covering 80% of all flats in the data. Depending on the room count, the coverage is between 54% (four-room flats) and 84% (two-room flats). The findings also suggest that in the examined cohort, every third to every second flat in each room count would be identical with the most common flat type of that room count. The hypothesis was that some recursion would occur because this vintage has often been criticized for its perceived monotonousness. Yet, the extent of the repetitiveness was surprising, considering that the buildings or their layouts were never factually standardized in Finland – only the production technology was. If full generalizability of the results is assumed amongst the apartment blocks of the examination period, the recognized types cover as much as one-third of all existing Finnish flats.

Although this paper is the in Finland in which the selection of representative types has been based on real data, the existing refurbishment studies utilizing the concepts of 'typical buildings' or 'typical flats' already demonstrate the advantages of the current findings. Besides creating new plans, the recognized types also allow evaluating the applicability of these case-based renovation studies for a larger stock of dwellings, thus possibly increasing their utility retroactively. Defining the typology of flats enables shifting from singular case studies to creating mass-customized alteration concepts that fit a wide range of dwellings with minimal modifications. If needed, the level of detail of such concepts could be increased further by studying dimensional variations of individual rooms or flats as whole entities. In addition, understanding the interior configurations of the units helps in studying the possibilities for combining or dividing them. As household sizes have changed considerably since the 1970s and keep doing so, this is a matter to consider when adapting the existing building stock to current and future needs.

On a broader scale, transformation potentials of housing estates or whole neighbourhoods could be evaluated more swiftly by first studying the suitability or adaptability of different flat types for various demographics. This can help to comprehend existing housing and possible development needs in a wider context. In addition to the apartments themselves, understanding which demographics the dwelling stock of a neighbourhood can house is useful in contemplating the extent and qualities of the required local services. When combined with studies addressing the structural properties of the buildings in question, the knowledge on flat types can also be used to better estimate the potential for renovation and the cost of such measures in the current building stock. In all, the types can help residents, designers, real estate managers and policy-makers to recognize the possibilities of existing housing and to better plan their future actions, be they home refurbishments or policy changes.

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DISCLOSURE STATEMENT

We assure that we do not have any financial interest or other benefit arising from the application of our research; neither do we have any conflicts of interest.

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ARTICLE
III

Accessibility improvement models for typical flats: mass-customizable design for individual circumstances

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ABSTRACT

Elderly housing policies in Finland emphasize ageing-in-place and pursue preparing the existing housing stock for the predicted increase of the aged population. Timely home modifications enhancing mobile accessibility are a focal target for these policies. This paper introduces the idea of mass-customizable architectural accessibility improvement models (AIMs) that have been developed for typical Finnish flats. The applicability and generalizability of an AIM designed for an archetypal two-room flat is tested by applying it to nine case buildings in the city of Tampere. The model was found to be beneficial for 42 of the 45 rooms in the research material.

KEYWORDS

Architectural design, home modifications, housing stock, interior spaces, refurbishment, universal design

INTRODUCTION

The populations of many developed countries are growing older (Giannakouris, 2010; Lanzieri, 2011; Suzman & Beard, 2011), but in Finland, the ageing is expected to be more rapid than in any other European country (Tuorila, 2014). This has made Finnish governments pay attention to the living conditions of the elderly and prepare for the increase of the aged population. Accessibility improvements were given a prominent position in the National Renovation Strategy for years 2007–17 (Ympäristöministeriö, 2007). Living at home was prioritized in legislation (Vanhuspalvelulaki, 980/2012) during the administration of the previous government, which also considered elevator retrofits, home modifications and increasing accessibility in the housing stock as focal housing policy targets for supporting the autonomy of aged Finns (Valtioneuvoston kanslia, 2011) and launched a Development Program for the Housing Conditions of the Elderly for the years 2013–17. The current, austerity-driven government is set to increase home care and services delivered at home, since they are considered to be more cost-efficient than assisted living facilities or institutional care (Valtioneuvoston kanslia, 2015).

Although the Finnish housing stock is one of the youngest in Europe (Hassler, 2009), a number of shortcomings have been detected with its age-friendliness (Sorri, 2006; Verma, Kilpelä & Hätönen, 2012; Kaasalainen, 2015). The first provisions on accessibility of buildings were issued in 1979, but they considered only public buildings. The regulation came to encompass residential buildings as late as in 1994, and at first, they only touched upon apartment buildings with four or more floors. The norms were extended to encompass low-rise housing in 2005. (Verma et al., 2012). Consequently, aged homebuyers have been found to prefer brand new homes due to bad previous experience from older dwellings (Hirvonen, Manninen & Hakaste, 2005). The Ministry of the Environment has estimated that only 10% of the existing housing stock is accessible (Väyrynen, 2014).

However, over 65-year-old Finns already make up 20% of the population, and the share is expected to grow to 28% by 2060. The increase will be especially significant in the oldest age classes. (Statistics Finland, 2015). The authorities' aim is that in future, 92% of over 75-year-olds would be able to live at home, while 89.5% of them do so at the moment (Ympäristöministeriö, 2012). In addition, permanent and temporary physical disabilities are estimated to affect 10% and 5%

of the population, in a respective order (RTS, 2011). In all, circa one-third of the current population could, thus, benefit from a wider existence of accessible homes.

Therefore, the target is to increase the share of accessible dwellings from the current 10% to 30% by 2030. The plan is to meet 60% of this target with refurbishment, 60% of which would take place in blocks of flats. The goal is to refurbish 14 500 flats annually, i.e. 250 000 flats by 2030. Since the emphasis of accessibility renovations has long been on elevator retrofits, the interest is now shifting to internal accessibility improvements. (Ympäristöministeriö, 2012). These are expected to touch on 7500 flats annually or 135 000 flats in total (Ympäristöministeriö, 2012), which equals to 10% of the stock (Statistics Finland, 2015).

The expert group that prepared the Development Program for the Housing Conditions of the Elderly concluded that the focus of accessibility improvements is to be placed on the 1960–80s mass housing for a number of reasons (Ympäristöministeriö, 2012). First of all, these three decades represent the most notable era of Finnish housing construction in terms of volume, making up 56% of all Finnish flats (Statistics Finland, 2015). Secondly, this stock is acknowledged to be in need of repair due to erstwhile underdeveloped building techniques and materials (Kaasalainen & Huuhka, 2015a), and the authorities see the coincidence of the ageing of buildings and the ageing of population as an opportunity to slip home modifications into the usual facade and plumbing renovations (Ympäristöministeriö, 2012). Thirdly, improving accessibility in this stock is less complicated than in older stocks, due to more spacious dimensioning, existence of elevators in some of the buildings and the lesser extent of heritage values (Verma et al., 2012). Fourthly, the stock accommodates a significant share of the older population (Lankinen, 1998; Kivi & Nurmi-Koikkalainen, 2007).

Purpose and goals of the paper

This paper is a continuation for previous research on Finnish housing stock and studies related to accessibility and elderly housing. The current authors are set to create a link between the two branches of investigation. The paper introduces the idea of accessibility improvement models (AIMs) that are based on typical flats and intended to facilitate the initiation of home modifications. In studying Finnish multi-story housing from the late 1960s to the mid-1980s, Kaasalainen and Huuhka (2015a) recognized 18 recurring flat types, which were found to cover over 80% of the flats of the era – in all, circa 30% of Finnish flats. Taking advantage of these findings, Kaasalainen (2015) analyzed accessibility problems occurring in these homes and developed AIMs for the six most common flat types that altogether encompass circa two-thirds of the 1960–80s stock, or one-fourth of all Finnish flats. The goal of the AIMs was to be applicable to a large number of homes with as few modifications as possible. (Kaasalainen, 2015). The purpose of the current paper is to enlarge the knowledge by testing the applicability of an AIM on randomly selected homes from the respective era. Based on the results, discussion is presented about the usefulness of the concept and the development needs observed.

AGEING-IN-PLACE AND HOME MODIFICATIONS

Benefits of ageing-in-place

Although housing policies pursuing ageing-in-place are often driven by the desire to reduce institutional care in order to achieve cost savings, at the same time it should be noted that aged people in many countries, including Finland, prefer to continue living at home (AARP, 2005; Bayer & Harper, 2000; Ewen & Hahn, 2014; Fänge & Ivanoff, 2009; Haapola et al., 2009; JCHS, 2013; Turcotte & Schellenberg, 2007; van Hoof, Blom, Post and Bastein, 2013; Warnes, 1993). The home has been found to constitute an important part of one's identity at an older age (Aminzadeh, Dalziel, Molnar & Garcia, 2010; Fänge & Ivanoff, 2009; Kivi & Nurmi-Koikkalainen, 2007) and living at home has been shown to have positive implications for the wellbeing of older people (Aminzadeh et al., 2010; Heywood, 2001). Its benefits for physical, mental and cognitive health arise from, as Aminzadeh et al. (2010) sum up, 'autonomy, affinity and constancy of environment; participation in activities of daily living and home maintenance as a source of physical and mental exercise; connection with friends and family, entertainment and reciprocation of hospitality; and residence in a specific neighbourhood, including social network of neighbors and access to community services' as well as from modulating 'the experience of an illness or decline'.

The role of home modifications

While housing is only one aspect of ageing-in-place (Horner & Boldy, 2008; Verma & Huttunen, 2015), the tendency towards living at home has been found to require paying more attention to the age-friendliness of home environments (Afifi et al., 2014; Verma & Huttunen, 2015). In Finland, one of the main reasons for moving to an assisted living facility is a housing stock that does not provide the elderly with enough support (Verma & Huttunen, 2015). Home modifications, though, have been found to have a positive effect on ageing-in-place (Heywood, 2001; Hwang, Cummings, Sixsmith & Sixsmith, 2011; Kajanus-Kujala, 2008).

The elderly who have had architectural modifications done in their home are more independent in daily tasks than those who have not (Fox, 1995; Petersson, Kottorp, Bergström & Lilja, 2009) and are likely to continue living at home for longer (Hwang et al., 2011). The improved functional abilities reduce the burden of family caregivers and strengthen the persons' psyche by enabling experiences of security, safety, comfort, control, mastery and self-efficacy (Tanner, Tilse & de Jonge, 2008). Furthermore, modifications ease home care (Sipiläinen, 2011; Kim, Ahn, Steinhoff & Lee, 2014) and can even participate in delaying mortality (Gitlin et al., 2009). At best, ageing-in-place, supported by home modifications, benefits individuals, their families, and the wider society.

Further considerations

It has been found that home modifications need to be done early enough in order to be beneficial (Petersson et al., 2009). This conclusion is supported by statements that emphasize the significance of the stability and familiarity of the home environment in the face of physical and cognitive decline (Aminzadeh et al., 2010; Horner & Boldy, 2008; Yeo & Heshmati, 2014). In this light, the Finnish governments' aim to prepare the housing stock for ageing in advance becomes more understandable.

The needs of the elderly are individual, and the variation in those needs has been found to increase as the number of older people increases (Bakker, 1999). Thus, although there are standards for accessibility, home modifications themselves must not be standardized. Therefore, the AIMs to be presented in the next chapter are based on multiple stages of improvements and alternative solutions.

In practice, a major consideration in engaging in home modifications is cost. Income has been shown to predict having home modifications and a conclusion has been drawn that modifications should be available at an affordable cost (Fox, 1995). Similar statements have been presented in several studies (Kajanus-Kujala, 2008; Marquardt et al., 2011; Verma & Huttunen, 2015). Therefore, the AIMs also consider residents' differing financial resources.

RESEARCH MATERIAL AND METHODS

Flat types

This study is based on the typology of flats (Figure 1) defined by Kaasalainen and Huuhka (2015a) for the buildings years 1968–85 and the AIMs that were developed for the most common of them by Kaasalainen (2015). As follows from the principles of typology (Argan, 1963), the types are not plans of any singular flats but fusions of typical properties of several flats (Figure 2). Kaasalainen and Huuhka (2015a) defined the flat types using plans of 320 apartment buildings with a total of 8745 flats. The most commonly occurring flat type, referred to with the code '2-1A', was chosen for the current study. It occurred in half (158) of the buildings. Figure 3 presents the type i.e. the theoretical flat in scale. According to Kaasalainen and Huuhka (2015b), this type covers 15.7% of all flats from years 1968–1985 and 35.0% of all the two-room flats built during those years. Furthermore, types 3-1A, 3-3 and 4-1A are similar apart for the additional rooms. This denotes that the AIM created for 2-1A can be useful for up to one-third of the era's flats. The present paper tests and evaluates the applicability of the AIM by applying it to a sample of nine randomly selected cases. Because the flat type is based on a large sample in which the variation of dimensions was very limited (see Figure 2), the hypothesis is that the AIM would be applicable to a clear majority of the cases.

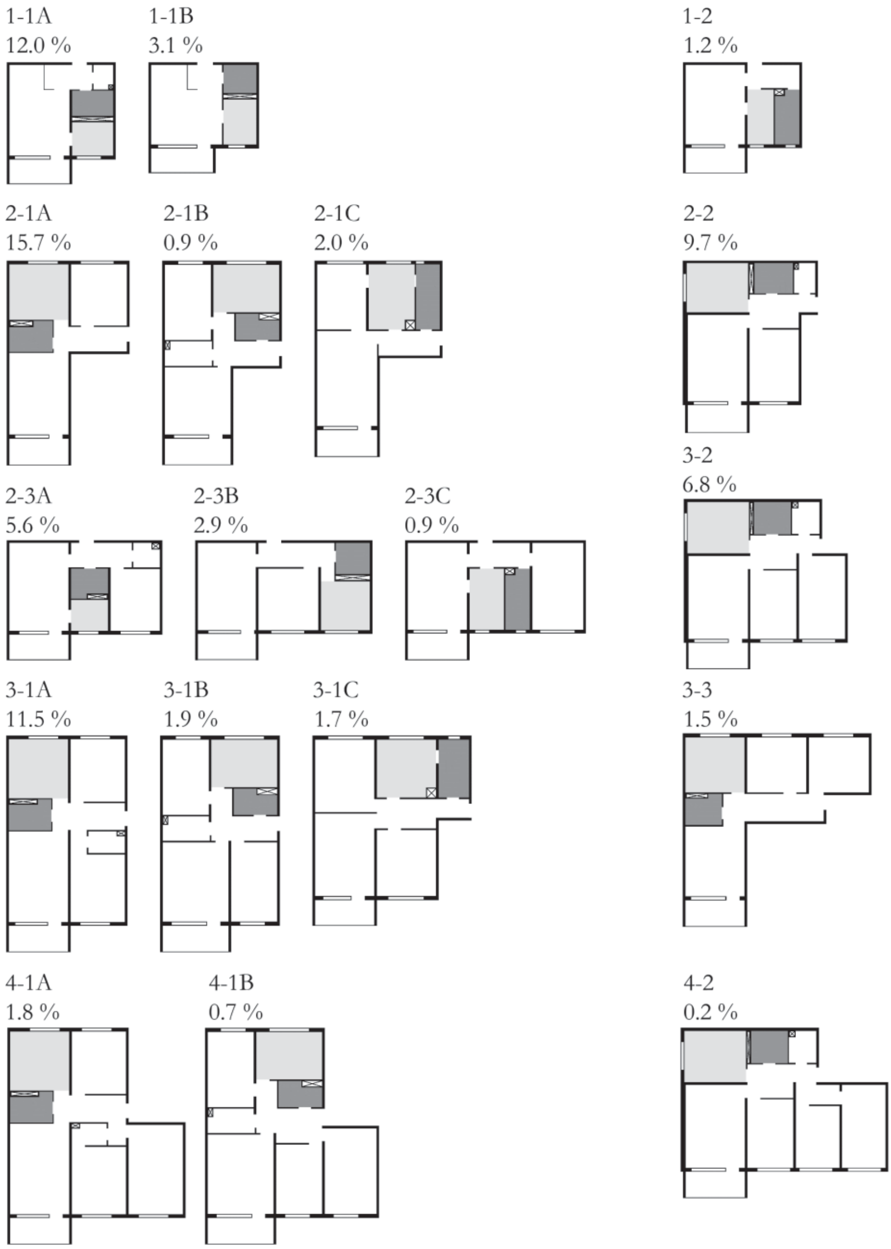

Figure 1. The typology of Finnish 1960–80s flats, scale 1:500. The codes of the types and their shares of the respective stock are given above the plans. Bathrooms are marked with dark grey and kitchens/kitchenettes with light grey. Types on the left are variations of the same main type, with the bathroom and a possible walk-in closet changing place but the main rooms staying put. The types on the right do not have subtypes. The figure is based on Kaasalainen and Huuhka (2015a; 2015b). In Kaasalainen (2015), AIMs were created for types 1-1A, 2-1A, 2-2, 2-3A, 3-1A and 3-2.

Figure 2. The method for creating the flat types in Kaasalainen and Huuhka (2015a) and the variation in the dimensions of the flats, scale 1:250. As the figure illustrates, the type plans (Figure 3) were the result of piling translucent line-weighted color-coded graphs that were made from the original plan drawings, aligned along the circled bathroom front wall, and by defining mean values for the dimensions of rooms and locations of windows and doors visually. (Kaasalainen & Huuhka, 2015a).

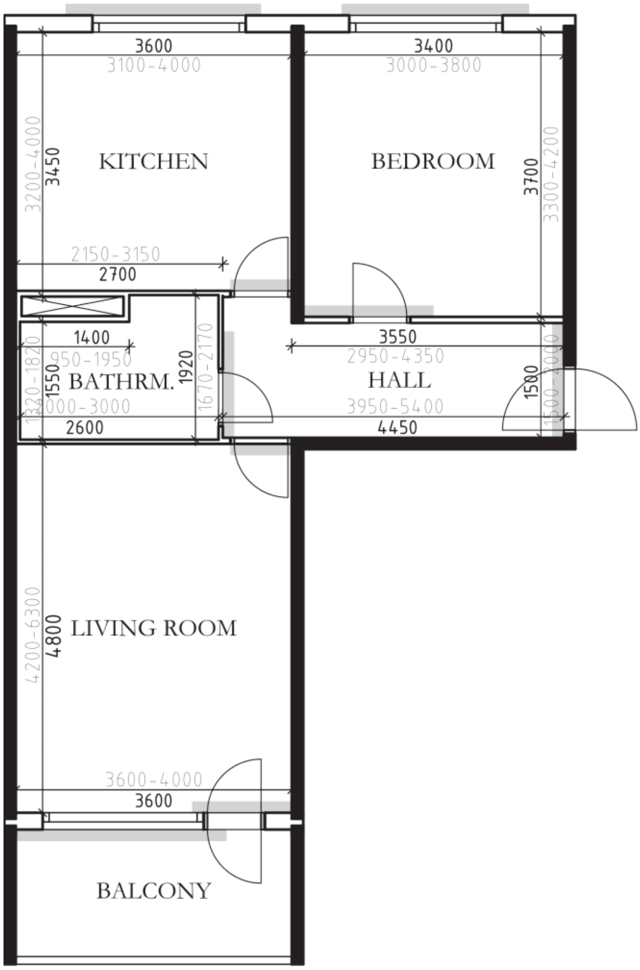

Figure 3. A theoretical flat representing a large two-room unit, typical dimensions, load-bearing structures, and fixtures in scale 1:100. The room dimensions used in the drawing are given in black; they as well as the drawn locations of doors and windows are mean values. The dimensions given in grey as well as the grey bars next to doors and windows represent the usual ranges for these features. Load-bearing walls are drawn in black. The figure is based on Kaasalainen and Huuhka (2015a) and Kaasalainen (2015).

Accessibility improvement models (AIMs)

The starting point for the development of the AIMs was the Finnish regulation for accessible housing design (RTS, 2006). Alas, comprehensive studies comparing various national accessibility-related building regulations were not found in English or Finnish. The closest to this was a comparison of minimum accessible toilet dimensions by Dion (2005), which is presented in Table 1 along with the Finnish requirements. Based on the figures, Finnish standards appear to correspond fairly well to other countries' guidelines, the Finnish requirements being stricter in most cases. Although the table presents dimensions specifically for the bathroom, the minimum door opening is universal throughout the flat and the other figures are likely to reflect more general spatial requirements as well. Furthermore, the bathroom has been noted to be the most common object of renovation in elderly people's households in Finland (Verma, Aalto, Anttila, Aro & Åkerblom, 2006), so it is of special interest.

Table 1. Minimum accessible toilet dimensions according to various standards. Sources: Dion, 2005; RTS, 2008.

	Minimum floor dimensions, mm		**Minimum door clear opening, mm**
	Dimension 1	**Dimension 2**	
ACCESS (UNKNOWN)	1500	1500	850
ADA (U.S.)	1525	1420	815
ANSI (U.S.)	1525	1420	815
AUSTRALIA	2000	1600	800
BEIJING (CHINA)	1600	1400	900
CSA (CANADA)	1500	1500	810
ENGLAND	2000	1500	1000
FIJI	2300	1900	850
FINLAND	1900	1500	850
KENTUCKY (U.S.)	1600	1422	813
NBC (CANADA)	1700	1700	800
UFAS (U.S.)	1524	1422	813

The development of the AIMs began with analyzing the problems of the flat types with the help of norms, guidelines, and research literature (Figure 4 and Table 2). The main focus was on mobile accessibility, although other issues such as cognitive problems were also considered. Since they largely encompass aspects that are not visible in the floor plan, such as colors and surface materials, which also have short service lives, it was not possible to analyze the current state of the stock or to portray the modifications in the plan format. Therefore, design guidance (on e.g. clearly distinguishable floor and wall surfaces and contrasting trims) was given as text in the original publication (Kaasalainen, 2015), as were instructions on lighting, materials, and alarm systems. Easy comprehensibility was also a key consideration in the changes made to the layout. Possible caregivers were taken into account where relevant, such as around the bed and the toilet, where the assisting space required by the Finnish regulation was ensured. In addition to these particular locations, the increased spaciousness in general makes it easier for the caregiver to assist the resident wherever necessary. Primarily, however, the solutions were designed for an independent occupant, therefore including, for example, a full kitchen. Specific choices of appliances were not considered, only the room needed to place and operate them.

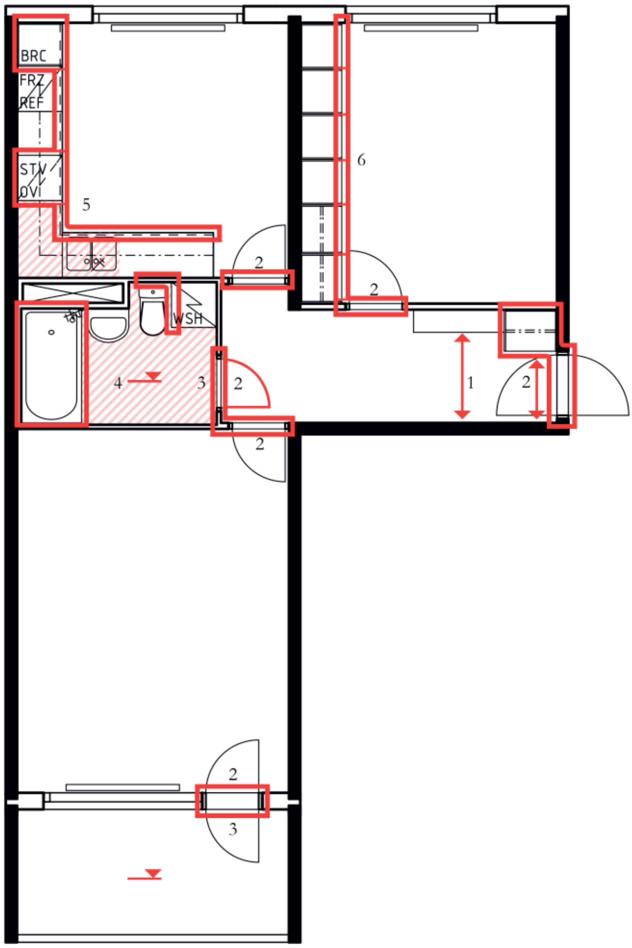

Figure 4. Accessibility problems in the flat type, scale 1:100. The key is given in Table 2. The figure is based on Kaasalainen (2015).

Table 2. Accessibility problems in the flat type 2-1A, see Figure 4. Accessibility problems in other flat types are similar.

Number in Fig 4	Location or object	Problems	Implications	Risks	Sources
1	Hall	Narrowness, especially near the entrance when original fixtures are in place.	Lack of space for a wheelchair or a walking aid.	Reducing autonomy in daily tasks.	Sorri, 2006; Kaasalainen, 2015
2	Doors	Narrowness; opening angle < 180°; two leaves (entrance and balcony); high thresholds (especially balcony and bathroom).	Hinders use with reduced walking ability, especially when using a wheelchair or a walking aid.	Risk of falling; reducing autonomy in daily tasks.	Sorri, 2006; Verma et al., 2012; Kaasalainen, 2015
3	Floor	Level difference between the bathroom and the balcony and the rest of the flat.	Hinders use with reduced walking ability; prevents use with a wheelchair.	Risk of falling; reducing autonomy in daily tasks.	Neuvonen, 2006
4	Bathroom	Lack of space; high threshold to tub; slippery, materials that are difficult to clean.	No space for assistance; hinders use with reduced walking ability, especially when using a wheelchair or a walking aid.	Risk of falling; reducing autonomy in daily tasks.	Sorri, 2006; Verma et al., 2012; Kaasalainen, 2015
5	Kitchen	Low and shallow toe kicks, no knee space, deep and narrow cabinets and closet, no dishwasher; sink in the corner.	Hinders use with reduced mobility, limits use with a wheelchair.	Reducing autonomy in daily tasks; risk of sustaining burns; risk of injury when reaching.	Sorri, 2006; Kaasalainen, 2015
6	Bedroom	Deep and narrow closets with hinged doors	Hinders use with reduced mobility, limits use with a wheelchair.	Reducing autonomy in daily tasks; risk of injury when reaching.	Kaasalainen, 2015

To account for individual conditions, such as accessibility needs and financial resources, and developments in them, the improvements were divided between four stages based on scope of action, level of cost and actorness (Figure 5 and Table 3). All the stages have been designed to aim at the same end result, allowing modifications to be staggered or individual measures to be picked without needing to implement all of those presented on that stage. Therefore, the stages are not a rigid progression as much as a set of categories for modifications—they can be implemented in the order of the stages, but this is not necessitated by the AIM. When it comes to bathrooms and balconies, the lower levels' ability to result in fully accessible solutions depends on the favourability of the original properties of the flat. In some cases, only some of the lower-stage modifications might be required to achieve full physical accessibility, but as a rule, extensive structural work is needed. This is because bathrooms tend to have a level difference with the rest of the flat and they are usually not large enough to meet the current accessibility standards.

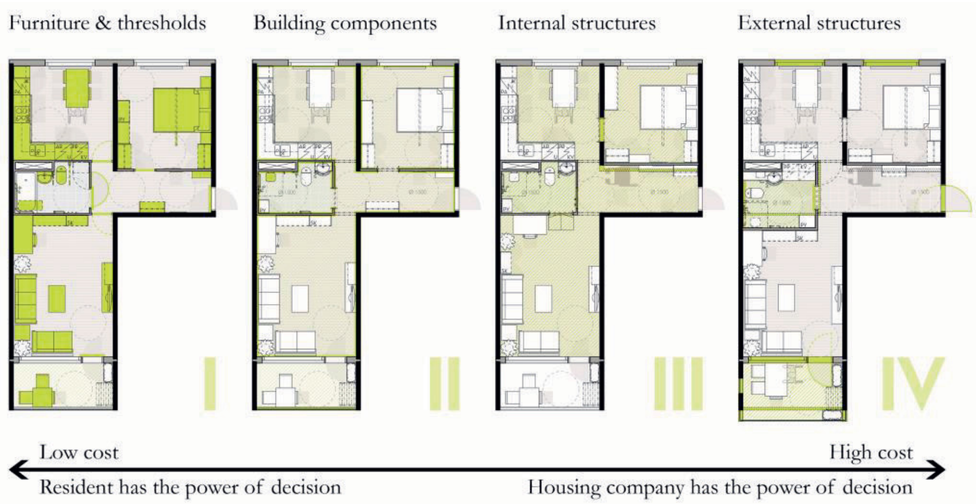

Figure 5. A four-stage AIM for a two-room unit, scale 1:250. The figure is based on Kaasalainen (2015). Rebuilding the bathroom is considered a part of 'external structures' because enlarging it and changes to drainage have implications for the flat below. See Table 3 for more detailed description of the modifications on different stages. The principle in developing the model has been that the changes made in the lower stages do not compromise the modifications suggested in the higher stages. The changes made are based on current Finnish accessibility regulations for housing design in conjunction with other literature on the subject (e.g. Bakker, 1999; Könkkölä, 2003; RTS, 2006; 2008; van Hoof et al., 2013). In addition to the material focused on the actual design part, a comprehensive literature review was conducted on the implications of ageing to gain an actual understanding the factors behind the design decisions (see the bibliography in Kaasalainen, 2015).

Table 3. Modifications on different stages of AIMs, see Figure 5.

Stage I	Stage II
Rearranging furniture; Changing fixtures not requiring structural changes; Adding grab bars and handles; Adding lifts and alarms; Removing or replacing thresholds; Removing or replacing interior doors.	Replacing hinged doors with sliding doors; Removing interior door frames; Replacing a non-fixed bathtub with a shower; Changing surface materials; Adding balcony glazing.
Stage III	**Stage IV**
Complete or partial dismantling of interior walls; Enlarging doorways and installing pocket doors; Replacing a fixed bathtub with a shower; Changes to floors and ceilings not limited to surface materials.	Structural work in the bathroom such as removing a level difference or moving the walls; Changes to the façade walls such as replacing and enlarging windows; Replacing or enlarging the balcony.

The 4th stages of the AIMs consist of three exemplar customization alternatives (Figure 6 and Table 4): the baseline is for an independent wheelchair user; the second alternative is for a visually impaired resident that uses a walker; and the third one is for a resident that receives care on a regular basis. The differences lie mostly in furnishing and lighting, all the alternatives solutions for which have been designed to be interchangeable between the variants without structural changes. The option of having two separate beds instead of a double bed was incorporated into the design for a visually impaired resident. One variant presents a situation in which a wheelchair for outdoor use must be stored inside the apartment, requiring space to be arranged in the hall. Studio flats excluded, the caregiver variant includes personal sleeping and storage space for the caregiver (a bedroom or a sleeping alcove). (Kaasalainen, 2015).

Figure 6. Customization alternatives for the 4th stage, scale 1:250. A is for a wheelchair user; B is for a visually impaired resident using a walker; and C is for a resident receiving care on a regular basis. Table 4 elaborates on the differences. The figure is based on Kaasalainen (2015).

Table 4. Customization alternatives for the 4th stage of the AIM, see Figure 6.

Location	IV A (baseline): A wheelchair user and a fully functional resident	IV B: A wheelchair user and a visually impaired walking aid user	IV C: A wheelchair user staying mostly in bed and a temporarily residing caregiver
Whole flat	Accessibility, safety and usability for an independently functioning wheelchair user, room for basic assisting. Grab bars or provisions for them added where needed. Materials, though not visible in the plan, should be easy-to-clean, non-allergenic, non-slippery and colored appropriately for cognition.	Basic lighting plan, applicable to all variants. Includes both general illumination and specific lighting such as at work areas, inside closets and around mirrors. Color choices, though not visible in the plan, are important to help perceiving the environment, if some degree of vision remains.	Details of the layout are more compact than in other variants, since the fully functional caregiver performs the daily chores, such as cleaning and cooking.
Living room	Area slightly reduced to increase space in bathroom. Furniture arranged to ease use, have room for the wheelchair user and to provide a barrier-free access to the balcony door.	The number of furniture reduced to have more room for both residents using mobility aids.	The resident's bedroom moved to the living room for a more comfortable environment, more space for assisting and better access outside, either visual or to the balcony. Bed replaced with an adjustable bed with space on both sides; sliding door added for privacy.
Bedroom	Furniture changed and repositioned to ease access.	Two separate beds to provide access for ambulatory aid for both residents.	Original bedroom furnished as a private room for the temporarily residing caregiver.
Kitchen	Appliances and fixtures changed to ease access and use with reduced mobility.		Kitchen organized to be mainly used by the fully functional caregiver.
Hall	Increased space near furniture and for storing a wheelchair for outdoor use.	Storing the wheelchair for outdoor use is assumed to be possible outside the flat; if not, the hall should follow one of the other variants.	Wheelchair for outdoor use stored in the hall; storage is more compact as the use is infrequent and facilitated by the caregiver.
Bathroom	Increased space for use and basic assisting, added room for laundry.		More assisting room provided in the bathroom by moving the toilet seat further from the wall and extending the shower area; washer/dryer stacked to save space as they are used by the caregiver.
Balcony	Increased space through extension or replacement of balcony.	The number of furniture reduced to have more room for both residents using mobility aids.	

All the AIMs were peer-reviewed by an architect and a researcher of accessible architecture Marta Bordas Eddy who is a wheelchair user and a specialist in universal design and, since the original publication (Kaasalainen, 2015) is a thesis, by a group of scholars consisting of professors and senior lecturers in Tampere University of Technology School of Architecture.

The current study utilizes the baseline version, i.e. the alternative customized for a wheelchair user, presented in detail in Figure 7 and Table 5. This is the AIM the applicability of which is evaluated to randomly selected flats of the corresponding type.

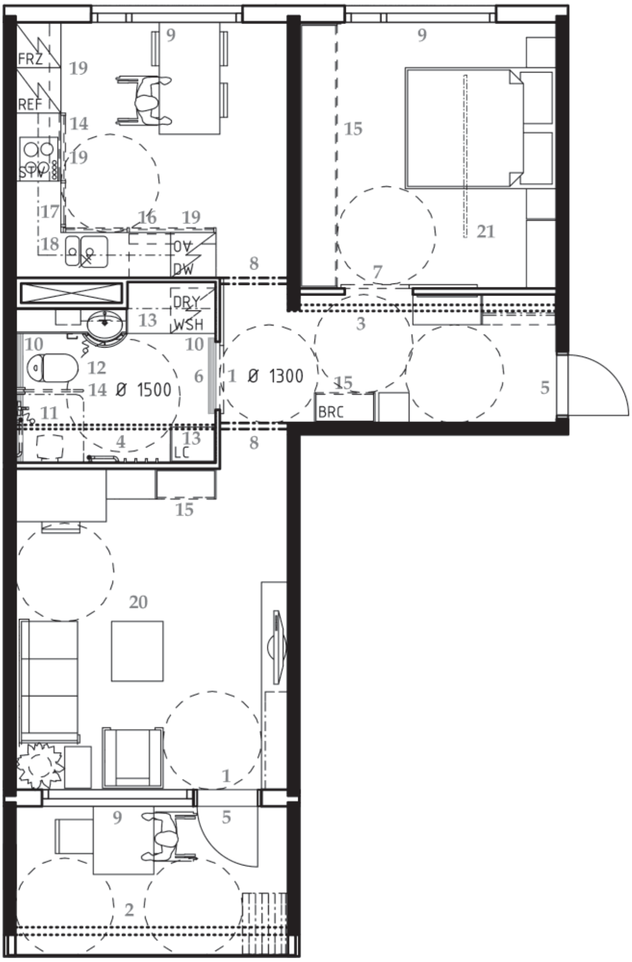

Figure 7. Accessibility improvement model, 4th stage plan customized for a wheelchair user in scale 1:100. The figure is based on Kaasalainen (2015). The key is given in Table 5.

Table 5. 4th stage modifications in detail in flat type 2-1A, see Figure 7.

Number in Fig 7	Modification	Purpose	Stage of origin
1	Level difference removed between hall and bathroom as well as living room and balcony.	Ease moving; reduce risk of falling; enable use with a wheelchair.	IV
2	Balcony extended or replaced with a larger one and equipped with glazing.	Enhance use.	II / IV
3	Bedroom wall pulled back.	Increase spaciousness in the hall to enable wheelchair storage and ease moving.	III
4	Bathroom extended towards the living room.	Increase spaciousness in the bathroom to enable use with a wheelchair or a walking aid and to ease assistance.	IV
5	Old doors replaced with larger, single leaf doors with no thresholds.	Ease use and moving.	I
6	Larger entrance to the bathroom with a sliding door and without a threshold.	Ease use; enable use with a wheelchair.	IV
7	Sliding door to the bedroom.	Ease use.	II
8	Kitchen and living room doors and their frames removed.	Ease moving.	I / II
9	Windows changed to ones with lower sill.	Ease use of window mechanisms; increase visibility when seated.	IV
10	Trench drains added.	Drain the floor when the threshold has been removed.	IV
11	Bathtub replaced with an accessible shower.	Ease use; enable use with a wheelchair.	II / III
12	Toilet seat and sink moved.	Ease assistance and the transfer between a wheelchair and the toilet seat.	II / IV
13	Added a laundry closet and a washer/dryer combination with increased table space.	Ease use.	I/ II / IV
14	Grab bars added where needed, structural requirements for future installations considered in relevant places.	Ease use; reduce the risk of falling.	I
15	Closets replaced with shallower and wider models with sliding doors.	Ease use.	I
16	Kitchen cabinets replaced with drawers.	Ease use.	I
17	Lowered upper cabinets with ability to pull down if needed.	Ease use.	I
18	Knee space and deeper/taller toe kicks added.	Enable use with a wheelchair or when seated.	I
19	Dishwasher added; a stove/oven and a freezer/refrigerator replaced with separate appliances.	Ease use; reduce risk of sustaining burns.	I / IV
20	Furniture rearranged.	Ease moving and provide space for a wheelchair user.	I
21	Lift installed above the bed.	Ease transfer between the bed and a wheelchair.	I

Cases and evaluation criteria

The research material for testing the applicability was picked from the city of Tampere, Finland, since the authors had easy access to the archives. The sample is random apart from the facts that the buildings were taken 1) from neighborhoods known to have blocks of flats from the year range of interest (1968–85) to minimize unnecessary searching; and 2) as evenly throughout the year range as possible in order to cover the whole period. The material initially consisted of twelve buildings, nine of which exhibited flats of the studied type. All flats of the same type were identical within their respective building, making the number of plans that form the research material also nine. These plans (Figure 8) are later referred to as 'comparison flats'. An attempt to apply the baseline version of the 4th stage of the AIM was made to each of them. The applicability of the AIM was studied in ArchiCAD architectural design software on a room-by-room basis according to the criteria given in Table 6.

Figure 8. The research material, i.e. the plans of the nine comparison flats corresponding to the flat type in question, scale 1:250.

Table 6. Criteria of applicability of the AIM.

Applicable without changes	Applicable with changes to the layout	Applicable with additional structural changes	Not applicable
The room of the comparison flat is as large as or larger than in the theoretical flat and of a suitable (similar) shape.	The AIM can be implemented by moving fixtures or furniture, which can still be placed accessibly.	The AIM can be implemented by conducting structural changes that are not proposed in the AIM and that do not compromise the function of the adjacent room(s).	The AIM cannot be implemented without compromising the functionality of the current room or the adjacent room(s) even with structural changes.

Limitations of the study

The sample behind the flat type on which the applied AIM is based on covered 51 cities from different parts of the country (Kaasalainen & Huuhka, 2015a), whereas the sample of the current study encompasses buildings from only one city. However, Kaasalainen and Huuhka (2015a) detected no difference in the design between different locations, which is also supported by many other studies noting the uniformity of the Finnish building stock of the researched era (Mäkiö et al., 1994; Neuvonen, 2006; Huuhka, Kaasalainen, Hakanen & Lahdensivu, 2015). The flat production from the 1960s to the early 1980s was contractor-driven and accordingly focused heavily on minimizing construction costs by keeping variation to the minimum (Neuvonen, 2006). This also meant that the regulations for various minimum dimensions also became the maximum, leading to further homogenization in design, along with reusing the same plans again and again. Figures 1 and 2 manifest the results of this development. Therefore, the limited geographical coverage of the sample should not have a significant effect on the results of the study.

Although the AIMs have been developed for six flat types, this paper investigates only one of them. Based on the observations on the other flat types made by Kaasalainen and Huuhka (2015a), the majority of the contemporary Finnish dwelling stock in blocks of flats should be comparable to the flat type examined in this study when considering the applicability of mass-customizable models. In all, 9 of the 18 flat types identified by Kaasalainen and Huuhka (2015a) can be considered variations or extensions of the layout presented herein and the rest follow similar design principles; various functions are clearly separated into their own rooms, each of which is directly accessible from the hall—with the exception of the kitchenette in the smallest flats. As the dimensioning of flats is based on prefabricated construction technology and guidelines that were shared by all contractors (Kaasalainen & Huuhka, 2015a), room sizes do not differ notably between different flat types or buildings. Flats with more rooms obviously provide more options for case-by-case problem solving by rearranging functions. As this rearrangement is more of a matter of individual customization after establishing the baseline with the help of the AIM, evaluating the concept in the chosen flat type should be a reasonably reliable indicator of its applicability on a broader scale.

Lastly, the AIMs have four stages, but this study only examines applying the most comprehensive stage. However, over half of those modifications originate from previous stages and the 4th stage encompasses the majority of lower-stage changes (see Tables 3 and 5). Therefore, applying the 4th stage should give a good indication of the applicability of the lower stages as well. The bathroom makes an exception to this rule, since the 4th stage encompasses an extension of this space. Therefore, the applicability of the lower-level changes to the bathroom is evaluated separately. The 4th stage also encompasses three customization alternatives, only one of which is tested. However, the differences lie mostly in interchangeable furnishing variants, of which the chosen one requires the most space, since it has a double bed and is intended for complete wheelchair accessibility. Therefore, the two other alternatives are definitely implementable if the chosen version is, but not necessarily vice versa.

RESULTS

Table 7 presents the results of applying the 4th stage of the AIM (Figure 7) to each of the nine comparison flats (Figure 8). In previous literature, the hall and the bathroom have been stated to be the most problematic spaces in this building stock, primarily due to the lack of space (Sorri, 2006; Verma et al., 2006). This was also evident in many of the comparison flats. Even so, only one of the halls in the comparison flats required more structural changes than the repositioning the non-load-bearing wall next to the bedroom suggested in the AIM. Three of the halls could accommodate the proposed new layout without the partition wall changes inbuilt into the AIM.

Table 7. Applicability of the AIM to the flats of the research material (Figure 8).

	Living room	Hall	Bathroom	Bedroom	Kitchen
Flat 1	□	▪ (grey)	▪ (grey)	□	□
Flat 2	□	▪ (grey)	■	▪ (grey)	□
Flat 3	□	■	▪ (grey)	■	–
Flat 4	□	▪ (grey)	□	–	□
Flat 5	□	□	▪ (grey)	■	–
Flat 6	□	▪ (grey)	□	□	▪ (grey)
Flat 7	□	□	□	▪ (grey)	▪ (grey)
Flat 8	□	□	□	□	□
Flat 9	□	□	▪ (grey)	□	□

□	Applicable without changes
▪ (grey)	Applicable with changes to layout
■	Applicable with additional structural changes
–	Not applicable

Enlarging the bathroom is also a feature inbuilt into the 4th stage of the AIM. As expected, all the bathrooms of the comparison flats needed to be increased in size to accommodate the fully accessible, wheelchair-usable layout. The initial dimensions of the bathrooms varied considerably, but only one of them required more structural changes than moving one wall and the accompanying floor work. As the dimensions of the bathrooms stayed within the ranges of the flat type (Figure 3), the lower stages of the AIM, i.e. modifications that increase but cannot guarantee accessibility, can also be deemed applicable insofar as the interior of the room is considered. In flats 2, 3, 7 and 9 applying the third or the fourth stage of the AIM required removing the adjacent walk-in closet (the sauna in flat 9).

As expected due to its lack of fixtures and general spaciousness noted by Kaasalainen (2015), the living room presented the least problems for the application. Even after expanding the bathroom, all studied living rooms could easily accommodate the layout proposed in the AIM. Unexpectedly, bedrooms and kitchens proved to be the most challenging rooms for the application of the AIM.

Most of the difficulty in applying the model to the bedrooms was caused by the need for a two-person bed and the closet space required for two people. All of the bedrooms—even the one marked 'not applicable'—could easily fit a one person bed with a bedside table and closets. As the circa 60m² one-bedroom flat is considered as a home that should be able to house a couple, the AIM had to be deemed inapplicable if the bedroom could not fit a queen bed with enough space on both sides for one wheelchair user and one fully functional senior. In parallel, a conclusion can be drawn from observing the research material that these flats simply cannot accommodate an accessible queen bed in the room intended to act as the bedroom. If a small living room can be accepted, the problem may be solved by switching the functions of the bedroom and the living room, but that is a solution the AIMs do not encompass. However, architects designing home modifications can apply the principles presented in the AIM for the living room and the bedroom even in cases where their functions need to be switched.

As for the kitchen, its size and the location of the entrance are generally fixed in the flat type due to both structural and spatial reasons. Therefore, the AIM was mostly either applicable as such or not at all. The main problem was the amount of free counter space and room for drawers after placing all the necessary appliances. Singular improvements (such as replacing the stove with a hob and an oven; or replacing the refrigerator-freezer with separate appliances; but not both) could be performed at the expense of storage space. The dining table, on the other hand, fit reasonably well even in the two kitchens where the overall design was not deemed applicable due to the aforementioned factors.

Expectedly, by far the most common problem among all the flats was the lack of space. Since the flats are strictly partitioned to individual rooms by function, often bound by load-bearing walls, the opportunities for changing the area distribution without major renovations are limited. However, the rooms that have been noted to be the most problematic in terms of accessibility, i.e. the hall and the bathroom (Sorri, 2006; Verma et al., 2006), were also the ones that could be enlarged the most in the comparison flats. On the other hand, in the kitchen and the bedroom, which had the least potential for spatial change, it is easier to make compromises based on individual needs simply by changing the furniture and fixtures. Swapping the locations of the living room and bedroom is also simple due to all of the rooms being directly accessible from the hall.

The connections between rooms did not vary much set against what was presented for the flat type by Kaasalainen and Huuhka (2015a). One of the bedrooms was accessed through the kitchen and the precise location of the doors varied but not enough to affect the application of the AIM. The location of load-bearing walls also matched the flat type acting as the basis of the AIM in all but one flat, where the wall between the kitchen and the bedroom was non-load-bearing, easing relocation.

The vertical drain was located as expected, next to the bathroom, in every flat, although its size and shape varied. Again, this variation was not major enough to affect the refurbishment plan.

On the level of the entire dwelling, the AIM was fully applicable to six of the nine flats. In five of these, no additional structural work was required. In the flats where the model was not fully applicable, the problem was restricted to a single room. On the level of individual rooms, the AIM was suitable for 38 of the 45 rooms studied without structural changes. In 26 of them, applying the model required no changes at all. In four rooms, structural changes were needed. In all, the AIM was applicable with or without modifications to 42 of the 45 rooms.

CONCLUSION

This multi-case study introduced the idea of architectural accessibility improvement models (AIMs) developed by Kaasalainen (2015). The four-stage AIMs have been designed to support older adults' functional abilities and, thus, to help them maintain autonomy in daily life. The changes to flat layouts also ease assistance in home care. Therefore, the repertoire of modifications presented in the AIMs can enable the elderly to continue living at home for longer, which has previously been shown to have positive implications for their health. Since encouraging ageing-in-place by increasing the accessibility in the 1960–80s housing stock is also a focal goal in the Finnish elderly housing policy, the work presented herein may participate in meeting that target.

The purpose of the current paper was to test the applicability of an AIM created for a prevalent two-room flat type in nine case buildings in order to evaluate the usefulness and development needs of the concept. The experiment showed that without customization procedures, a straightforward flat-wide design (e.g. an accessibility improvement plan based on a singular case study) would not be widely applicable enough to work as a generalizable model. The degree of variation in the amount and distribution of space available means that unless the plan is designed for a severely restricting situation, parts of it will likely be unsuitable for a specific target flat. Therefore, it is important that the AIMs cater for customization in the application phase. Based on the results, the design of the AIMs was successful in spaces recognized as problematic in previous literature, i.e. bathrooms and halls.

However, the experiment revealed that kitchens and bedrooms, which the literature does not highlight, can also be problematic with regard to accessibility and therefore deserve more attention.

Essentially, the results showed that the AIM was fully applicable to two-thirds of the studied cases, which is a clear majority and corresponds, thus, to the hypothesis. The coverage was even more significant on the level of individual rooms (42/45 rooms i.e. over 93% of rooms). Even if a flat-wide model isn't always applicable, even partial home modifications can be sufficient in many cases due to the variation in individual needs. The AIMs cannot be expected to reach the coverage of their respective flat types in the housing stock, since the dimensions of these 'theoretical flats' are mean values. Ultimately, the overall applicability of the concept of AIMs is more reliant on the repetitiveness of the flat designs than the specific layouts exhibited. The applicability of a specific AIM, on the other hand, is mainly determined by the similarity of the physical dimensions between the AIM and the targeted dwelling—especially when it comes to load-bearing structures and the location of vertical drainpipes.

Improving the direct applicability of a flat-wide AIM calls for supplemental plans for individual rooms to account for more notable variation in dimensions. This is especially true for rooms that are difficult to expand—for example the kitchen in the flats of this study, which was in all but one case practically unexpandable due to being bordered by a façade, a load-bearing wall and the bathroom with a wide drain. In practice, this would mean defining the smallest room size that can still be renovated to be accessible while retaining its functionality and using that as a basis for the supplemental plan. Although the use of supplemental partial plans would somewhat decrease the simplicity of the concept, the result should still enable a more tailored and communicative approach than a written set of universal guidelines. The number of supplemental plans required, at least in the Finnish stock of flats, is also likely to be rather small considering the extent of regulation for dimensions and the proclivity of contractors for sticking to the legal minimum recognized by Neuvonen (2006). Even with the addition of partial plans for more specific situations, the concept of AIMs, based on a verifiably representative typology of flats, seems suited for creating an easily understandable, widely applicable 'catalogue' of modification possibilities.

It should be noted that the degree of accessibility achieved with the help of an AIM can only be as good as the degree of accessibility in the AIM itself. The development of the tested AIM was based on peer-reviewed expert work in which the current best practices were applied in the context of typical Finnish flats, that is, translated into plan drawings. It can be argued that this was a just choice, as it has been found that when it comes to accessibility improvements, the residents usually settle for less than what professionals would do (Heywood, 2011; Verma et al., 2006). Furthermore, the Finnish accessibility standards appear to be on a fairly good level in international comparison, if the minimums for door and toilet dimensions given in Dion (2005) (see Table 1) are taken as its evidence.

In addition, it should be acknowledged that the current study tested the customization of the AIM for different flats, not different needs. As the latter is also an essential part of the concept, in future it should be studied how the AIMs support achieving this target. Here, the architect's capability to understand the resident's condition and to apply the AIMs to meet their needs is likely to have a significant role. Future studies should also investigate if the models are communicative enough towards the client in their current form, or if the presentation should be taken to 3D, for instance. Such a representation could not only help the users engage more in the design of the modifications but also encompass modifications for supporting cognitive health, such as color and material choices, which cannot be easily portrayed in the current plan format.

Although the AIMs already encompass a rough progression of effort and cost, embarking on modifications could be less daunting for homeowners if, in future, the AIMs could be combined with cost estimates. Furthermore, AIMs could also act as a basis for developing commercial mass-tailored home modification concepts that are more affordable to the resident than individual projects. For productization to be able to provide customers with more satisfying outcomes for affordable prices, enterprises must be able to define the content and price of the service in detail (Jaakkola, Orava & Varjonen, 2009). Mass-customizable AIMs designed for typical flats would seem to meet this criterion.

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ARTICLE
IV

Reusing concrete panels from buildings for building: potential in Finnish 1970s mass housing

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ABSTRACT

A remarkable share of European mass housing was built with large-panel systems during the 1960s and 1970s. In many countries, this stock is already being demolished or demolition is discussed due to vacancies or social problems. This trend may result in the creation of an unforeseeable amount of concrete waste. Simultaneously, EU has issued the Waste Framework Directive aiming at reuse instead of recycling. Unlike in situ cast concrete, reclaimed prefabricated concrete panels from mass housing carry the potential for reuse. The purpose of this study is to review the reuse potential embedded in Finland's mass housing stock from the perspective of the dimensions of the panels and spaces, i.e. their suitability for architectural (plan) design. The research material consists of architectural drawings of 276 blocks of flats that contain over 26 000 prefabricated wall panels and nearly 14 000 hollow-core slabs, the dimensions of which are compared to current norms and guidelines for dimensioning living spaces. The technical prerequisites for reuse are reviewed with the help of literature. The study results in identifying an inventory of panels typical to Finnish precast concrete construction, which, in principle, should not exist because the building plans were not standardized but were supposed to be unique. The panels are found to be still usable in architectural (plan) design of detached houses, which form one third of annual residential production in Finland.

KEYWORDS

Construction and demolition waste, deconstruction, dimensions, precast concrete panels, salvage, reuse

1. INTRODUCTION

The majority of the Finnish building stock is residential and 1970s was the peak decade in residential construction. At that time, most of the apartments were realized in high-rise mass housing with prefabricated concrete panel construction. This is in common for most European countries with notable mass housing stocks (Turkington, van Kempen & Wassenberg, 2004). During the last ten years, a public discussion on the demolition or preservation of these housing estates has accelerated in Finland. Large-scale demolitions have taken place elsewhere in Europe, especially in the UK, Germany, France, and the Netherlands because of vacancies following urban shrinkage and as an attempt to mitigate social segregation (ibid., p. 276; for Germany, Deilmann et al., 2009). Both these circumstances appear in Finland, too, in different parts of the country. Examples of demolitions of public housing with respective motives can be recognized here and there even though the demolitions have so far remained local and small in scale. However, should the demolitions of the contemporary mass housing stock accelerate, an unforeseen amount of concrete waste could be created. This applies not only to Finland but even more so to the countries that are already demolishing mass housing. Therefore, it has been suggested that old buildings should been seen as reserves for resources such as building materials (Agudelo-Vera et al., 2012; Thomsen & van der Flier, 2011).

At the same time, the European Union is tightening the demands for recycling construction and demolition (C&D) waste. The Waste Framework Directive defines a waste hierarchy according to which preparation for reuse is to be prioritized over destructive recycling as material (EU, 2008, p. 10). With its 70%-by-weight utilization target for C&D waste (ibid, p. 13), the directive puts a strong emphasis on recycling of heavy mineral materials. Concrete is a material that is easily recyclable in roadbeds; yet this kind of utilization is downcycling and ranks low in the waste hierarchy (Hiete et al., 2011). Researchers have warned that downcycling or even disposing of concrete will increase in Germany in near future if new sinks, such as new construction, are not promoted (ibid.). Indeed, manufacturing recycled aggregate concrete from crushed concrete is a more refined and higher-ranking option for the recycling of concrete. Unfortunately, it has a carbon footprint worse than virgin aggregate concrete (Asam, 2007); so what is gained on resource depletion is lost for global warming. Unlike in-situ cast concrete, prefabricated concrete panels may carry the potential for reuse. Some systems, such as the Dutch CD-20, have been designed for deconstruction and reuse (Kibert & Chini, 2000, p.103–109; fib, 2008, p.69–70), but the majority of systems do not have this asset. Nevertheless, several experiments on reusing panels from prefabricated housing have proven successful even though the panels were not originally designed for deconstruction. In addition to having a very low carbon footprint, reuse usually reduced the cost of new construction by 20–30%. (Huuhka, 2010a).

The research on reclaiming and reusing panels is most progressed in Germany (see e.g. Mettke, 2003, 2007; Asam, 2005, 2006, 2007; Mettke, Heyn & Thomas 2008). For example, panel inventories have been compiled from most widespread German systems to aid the design of new buildings (Mettke, 2003 & 2007). Some studies have also been conducted in the Netherlands (Coenen et al., 1990; Van Nunen, 1999; Naber, 2012; Glias, 2013) and Finland (Huuhka, 2010a; Saastamoinen, 2013; Lahdensivu et al., 2015) and some experiments have been carried out in Sweden (Addis, 2006, p. 25–26; Huuhka, 2010a, p. 110). While these experiences are generally encouraging, the results acquired from one building system may not be directly applicable to other systems because structural details, degrees of standardization and geographical distributions of systems may vary significantly. For example in East Germany (GDR), there were only a handful of different panel systems; they were used in the whole country; and the systems were highly standardized, including the panels and building plans (Blomqvist, 1996, p. 53–58). In Finland, then again, there were multiple factory-specific panel systems that were used locally; the national standard given in 1969 only aimed at standardizing the connections and the modular grid; and buildings were designed individually at all times (Hytönen & Seppänen, 2009, p. 116).

Although most of the aforementioned research has been published in local languages, the international scientific interest in salvage and reuse has been growing. The latest articles include e.g. Gorgolewski (2008), Gorgolewski et al. (2008), Gravina da Rocha and Aloysio Sattler (2009) and Pongiglione and Calderini (2014). Unlike this paper, none of the aforementioned contributions concentrate on concrete structures. The purpose of the current study is to evaluate the reuse potential embedded in the mass housing of Finnish cities with regard to the dimensions of the concrete panels, i.e. their suitability for new architectural design. Although the study situates in Finland, it may have relevance for other countries as well because Finnish panel systems were based on international examples. The research questions are as follows: What parts (e.g. exterior walls, interior walls, slabs) of mass housing were prefabricated and up to what extent? Do the panels come in recurrent sizes and if, which dimensions? Are these dimensions suitable for new construction and for which purposes?

2. BACKGROUND

As explained above, knowledge on deconstructing and reusing panels from one system may have a very limited applicability to other systems. Therefore, this section focuses on exploring existing knowledge on Finnish precast concrete construction that acts as the starting point for the current study. The first chapter presents an overview of the large-panel systems used in Finland. The second and third chapters concentrate on the technical opportunities and limitations for reuse. The fourth and last chapter looks into the influence of norms and design guidance.

2.1. Finnish concrete panel systems

Prefabrication came into use in Finland during the 1950s, first in non-residential construction (Hytönen & Seppänen, 2009, p. 38–57). The first fully prefabricated block of flats was constructed in 1959, and several significant construction companies shifted to panel construction in the beginning of 1960s (Hytönen & Seppänen, p. 53). In these early days, each panel factory had its own panel system, many of which were loosely based on French or Swedish systems (Hankonen, 1993, p. 141–145, 158–159; Hytönen & Seppänen, 2009, p. 51, 91). The differences localized in dimensions, connections, and other structural details. (Hytönen & Seppänen, 2009, p. 53–54). Architecturally, the differences between the systems were minor. The structural skeleton of lamellae blocks was a crosswall frame, in which crosswalls are load-bearing and longitudinal walls are non-load-bearing (Mäkiö et al., 1994, p. 62). Exterior walls were sandwich panels and floors were solid concrete slabs. Table 1 gives more details on the structures and dimensions. These factory-specific systems (Figure 1) were in use up to 1975 (Mäkiö et al., 1994, p. 72). Nonetheless, partial prefabrication remained the most common practice throughout the 1960s and early 1970s (ibid, p. 66). Most contractors used prefabricated walls and casted floors in situ while at least one major contractor did the opposite (ibid p.

66; Hankonen, 1993, p. 159). By 1966, 25% of public housing was fully prefabricated and 35% was partially prefabricated (Hytönen & Seppänen, 2009, p. 75).

Table 1. Dimensions of structures used in factory-specific panel systems. Sources: Mäkiö et al. (1994); Saastamoinen (2013).

Building part or structure	Dimension(s), mm
Floor height	2800
Room height	2600–2640
One-room panel, typical width	3000–3900
Two-room panel, typical width	6000–7200
Solid concrete slab, maximum size	3600 by 5400
Solid concrete slab, thickness	160–200
Load-bearing part of exterior sandwich panels, thickness	150–160
Load-bearing interior walls, thickness	150–160

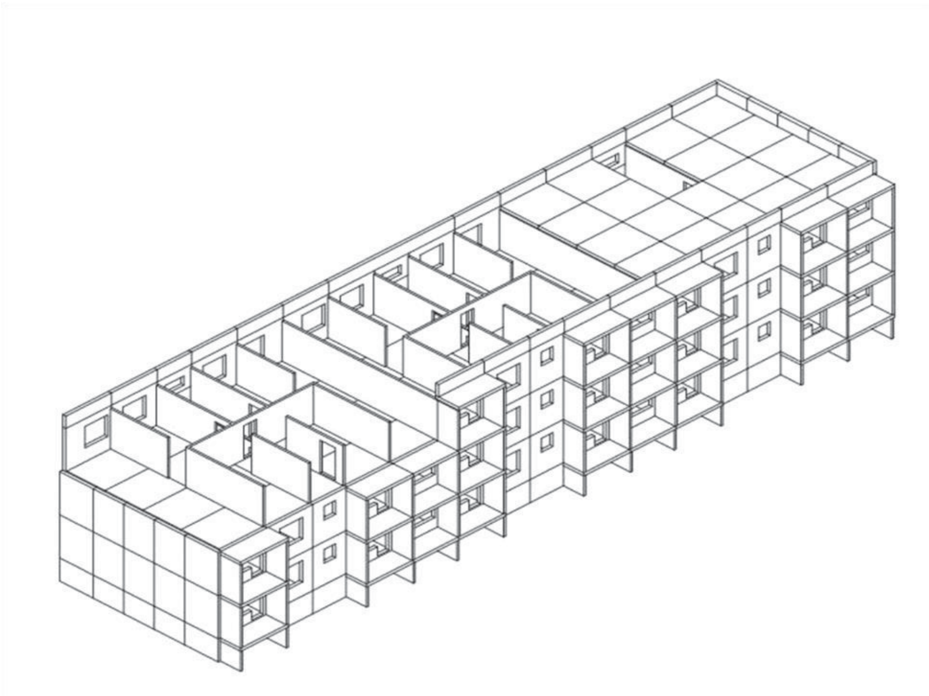

Figure 1. Finnish large-panel system used from 1960s to 1975. Both panels and slabs were room-size. Interior walls between rooms are load-bearing. (Remodeled from Mäkiö et al., 1994, p. 67).

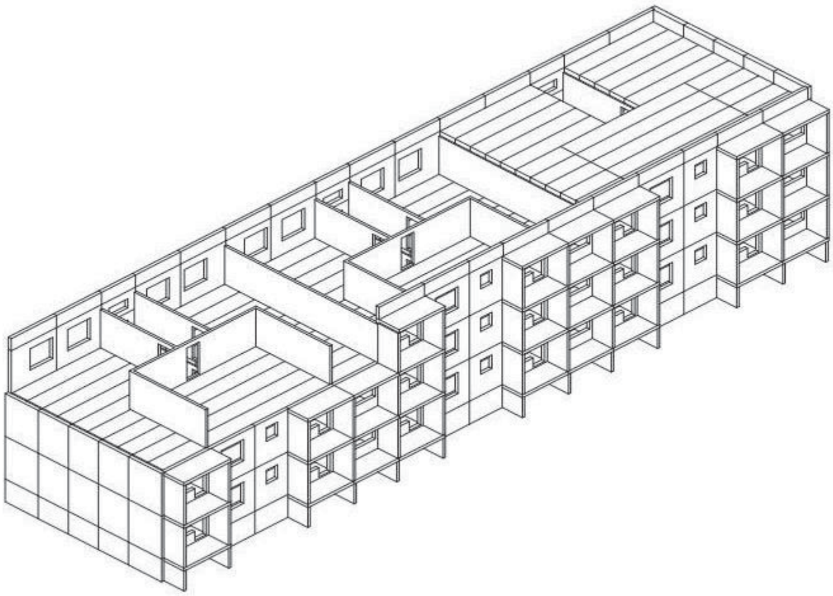

Figure 2. BES system. Main differences to the large-panel system (Figure 2) are the long-spanning hollow-core slabs and the subsequently smaller number of load-bearing interior walls. Only interior walls between apartments are load-bearing. (Remodeled from Mäkiö et al., 1994, p. 68).

In the end of the 1960s, the concrete industry launched a research project that aimed at the creation of one open standardized panel technology (Figure 2) called the BES (abbreviation of 'betonielementtistandardi', Finnish for 'concrete panel standard'). The main aim was to allow purchasing different elements, such as exterior walls, interior walls, slabs, balconies and stairs from different producers. (BES, 1969). The study, based on benchmarking a remarkable amount of panel systems in other countries, was completed in 1969 (BES, 1969). The first BES blocks of flats were inaugurated in 1971 (Hytönen & Seppänen, 2009, p. 107) and BES superseded the factory-specific systems during the 1970s. The most notable difference to previous systems was replacing solid concrete slabs with hollow-core slabs, similar to those used in Germany and Canada (Hytönen & Seppänen, 2009, p. 50, 104). Swedish-developed Nilcon or U-slabs, which represent prefabricated versions of upstand beams with integrated decks, were also used, but they were in the minority due to multiple weaknesses in comparison to hollow-core slabs (Hytönen & Seppänen, 2009, p. 106). These pre-tensioned slab types enabled longer spans and reduced the amount of load-bearing interior walls (Neuvonen, 2006, p. 150, 157), as can be seen by comparing Figures 1 and 2. In addition, connections were standardized; the number of alternative connections was reduced; and the pitches of the modular grid were fixed. Table 2 elaborates on the structures and dimensions in this system. BES has remained in use in the construction of blocks of flats and offices ever since. All in all, prefabricated concrete has dominated not only the construction of blocks of flats but also the production of business buildings (Hytönen & Seppänen, 2009, p. 325). Figure 3 shows the share of prefabricated concrete in Finnish building production since 1972.

Table 2. Dimensions of structures used in BES. Sources: BES (1969); Mäkiö et al. (1994).

Building part or structure	Dimension(s), mm
Floor height	2800
Room height	2500
Modular dimension, load-bearing structures	1200
Modular dimension, adjoining structures, horizontal direction	300
Modular dimension, adjoining structures, vertical direction	100
Load-bearing panel, possible width	1200, 2400, 3600
Non-load-bearing one-room panel, possible width	3000, 3300, 3600, 3900, 4200
Non-load-bearing two-room panel, possible width	6000, 6300, 6600, 6900, 7200
Hollow-core slab, width	1200
Hollow-core slab, maximum length	13000
Hollow-core slab, thickness	265
Load-bearing part of exterior sandwich panels, thickness	150
Load-bearing interior walls, thickness	180

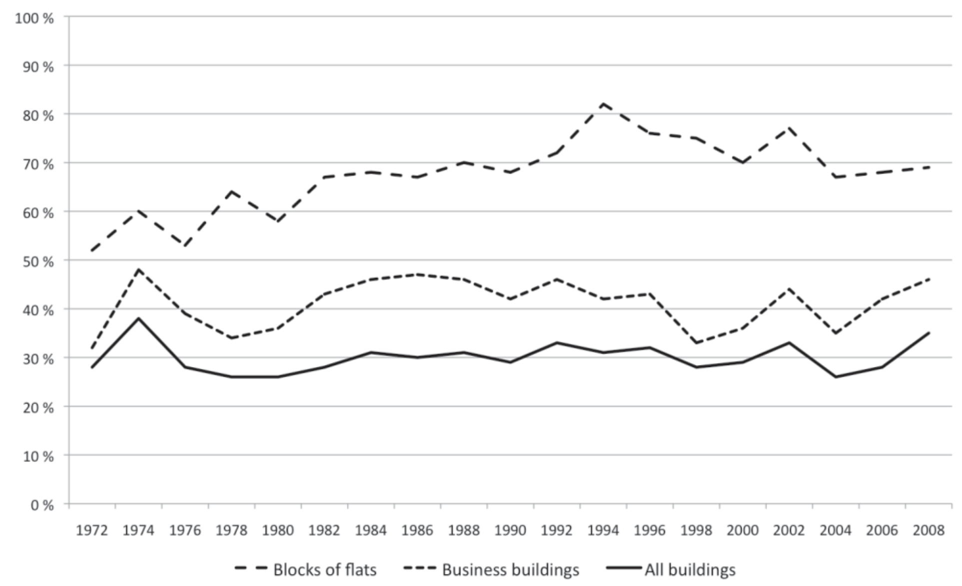

Figure 3. Share of prefabricated concrete in Finnish building production. (Remodeled from Hytönen & Seppänen, 2009, p. 325).

2.2. Connections, deconstruction and re-connection

The connections of the panels affect substantially the deconstruction process as well as the demounting process. Alas, the existing connections could not be studied with research material available for the current study, but the existing knowledge is included in this literary review. The options for connections are well documented in the literature. BES (1969), BES-suositus (1972) and BES-suositus (1979) represent the design guidance of the time, while Mäkiö et al. (1994) and Saastamoinen (2013) are later archival studies. The research materials of Mäkiö et al. (1994) encompasses 270 blocks of flats in Helsinki. Saastamoinen (2013) is a study based on a sample of 29 blocks of flats in Tampere.

The literature shows that in BES buildings, the connections are grouted. The grout transfers the compressive forces; in addition, there are rebars as tensile reinforcement in the joint. Hollow-core slabs are dowelled. Non-load-bearing exterior panels are usually self-supported or, more rarely, suspended from the ends of load-bearing interior walls. In vertical seams of load-bearing panels, there are either vertical steel bars threaded through steel loops that extend from the wall panels (Figure 4, left) or horizontal steel bars that have been bent into the seam (Figure 4, right). (BES-suositus 1979; Mäkiö et al, 1994, p. 100). Prior to BES, welded and grouted as well as bolted and grouted connections were also used. Like hollow-core slabs, solid concrete slabs were dowelled as well. Non-load-bearing exterior panels were usually suspended from load-bearing interior walls. Vertical seams were as in BES. (Mäkiö et al., p. 98–99).

As for the deconstruction of the typical connections, the Finnish experience is twofold. Deconstruction of blocks of flats was first experimented with in 2000, but it was found too laborious to be financially attractive for construction companies (Kauranen, 2001, p. 31–33, 38). Although reuse was neither planned nor attempted, the report concludes that the lack of applications is a barrier for reuse. The second effort took place in 2008–2010 during a neighborhood rehabilitation project in Raahe. In this case, deconstruction and small-scale reuse (Figure 5) were carried out successfully and resulted in savings in the construction costs. (Huuhka, 2010b). The 36% reduction of costs is equivalent to savings achieved in Germany (Huuhka et al., 2015).

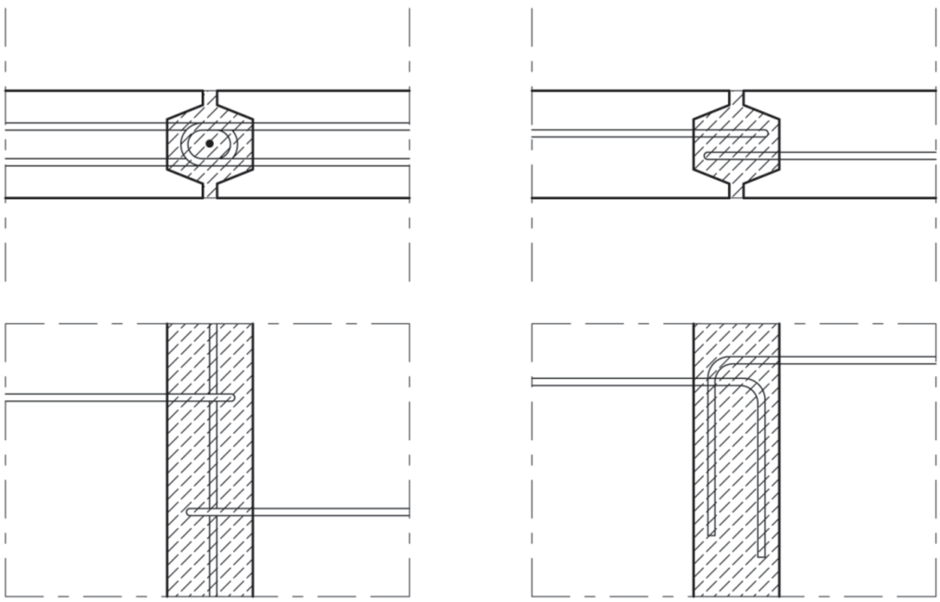

Figure 4. A steel loop connection (left) and a steel hook connection (right). (Redrawn from BES-suositus, 1972).

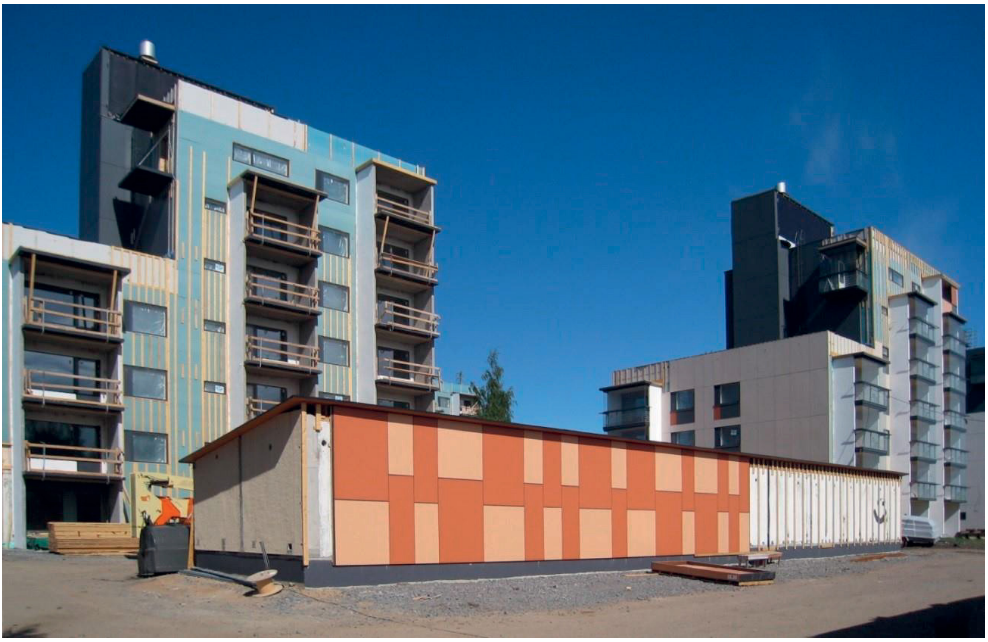

Figure 5. Construction site of Kummatti housing estate, Raahe. Partial deconstruction of apartment blocks (at the back) and reuse of panels for carports (at the front). Design by architects Harri Hagan and Petri Kontukoski. Photo in the courtesy of Petri Kontukoski.

Saastamoinen (2013, p. 101) estimates that original rebars and connection steels can be used for reconnection of old panels if the grouted joints are chiseled open carefully without cutting the steel bars. Another option is to use a diamond saw, but that may shorten the element and cut the rebars (Saastamoinen, 2013, p. 106–108). If the rebars are cut, new connection steel bars must be grouted to the edges of panels before grouting the panels together again. Non-load-bearing facade panels suspended from the ends of bearing interior walls are the easiest to reconnect (Saastamoinen, 2013, p. 99). According to Mäkiö et al. (1994, p. 78, 98–99, 133–134), this was the most common joint type used in Helsinki. However, according Saastamoinen (2013, p. 35), this technique was in the minority in the city of Tampere. A steel hook connection between load-bearing panels (Figure 4, right) is easier to chisel clean than a steel loop connection (Figure 4, left). The former seems to have been the most usual joint type in Tampere (Saastamoinen, 2013, p. 35) and it was also encountered in the Raahe deconstruction project. Mäkiö et al. (1994) do not report which was more common in their study. Other options for reconnecting are external or embedded steel connectors or encasing the structure in concrete (Lahdensivu et al., 2015). The last option was used in the project in Raahe (Huuhka et al., 2015).

2.3. Durability properties and damage of existing panels

Another issue to consider is the physical condition of the panels, which helps to assess the remaining service life. In a recent study, the durability properties of Finnish concrete facades were considered as poor, but the actual deterioration was found to be rather minor (Lahdensivu, 2012). There are two types of damage that are focal for reinforced concrete structures in the Finnish climate: firstly, frost damage and secondly, corrosion damage. Deterioration occurs as the result of both durability properties and exposure to stress conditions. The desired surface finishing influences the manufacturing technique of panels resulting in differences in the durability properties regarding both the degradation phenomena.

In Finland, concrete is considered to be fully frost-resistant if the material has a protective pore ratio of 0.2 and completely non-frost-resistant if the ratio is below 0.10. In 70% of existing concrete facades, this ratio is less than 0.15. The frost resistance varies depending on the surface type (Figure 6), and the manufacturing year. The worst properties are found in exposed aggregate concrete, ceramic tiles, and uncoated patterned concrete. In addition, concrete facades made before 1980 generally have poorer frost resistance than newer facades.

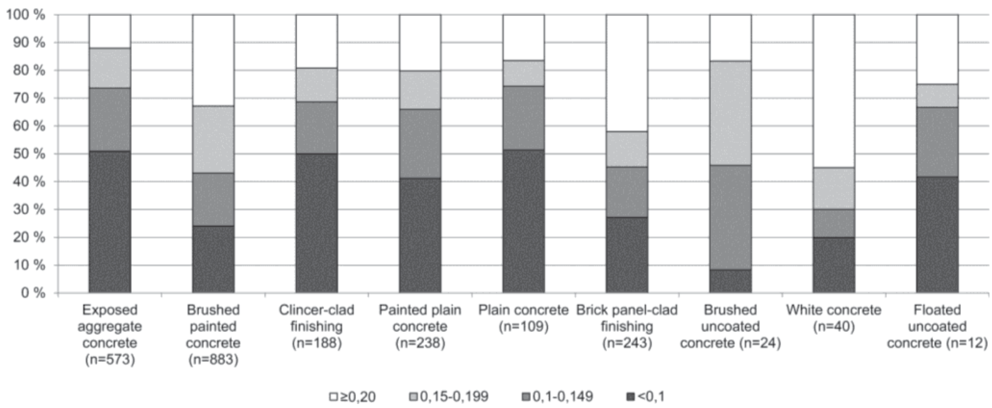

Figure 6. The distribution of protective pore ratio in different surface finishings of concrete facades (Lahdensivu, 2012).

As said, the actual frost damage depends on moisture behavior and stress conditions, such as the existence of proper waterproofing and the prevailing wind direction during rain (Lahdensivu et al., 2013). In most cases, insufficient frost resistance has not lead to far-advanced or widespread frost damage. Widespread frost damage has been observed in only 7.3% of studied facades.

The situation is very similar with corrosion as well. Widespread corrosion damage has been observed in only 5.7% of studied buildings. Due to higher amounts of annual rain, much more visual corrosion damage was observed in the coastal area than inland. (Lahdensivu et al., 2011). The corrosion has been induced by three factors: the use of corroding steel for reinforcement, too small cover depths of reinforcement and the carbonation of concrete.

The depth of the concrete cover on top of the reinforcement depends on the manufacture of concrete panels and the quality of work. Typically, 5–10% of reinforcement has crucially small cover depths (less than 10 mm). The smallest cover depths usually occur in ceramic tile finished facades, where the reinforcement is situated just behind the tiles.

In new concrete, the alkalinity of the material protects the reinforcement from corrosion. When concrete ages, it reacts with air and the alkalinity reduces. This process is called carbonation, and it makes the reinforcement more vulnerable to corrosion. Carbonation has widely achieved the reinforcement in all over 30 year old concrete facades and corrosion has already been possible for 20–30 years.

As stated, despite the poor durability properties of existing concrete panels, there is relatively little visible damage in them. The damage is typically local and can be repaired rather easily with patch repairs and protective coatings. This kind of repair extends the service life with 20–25 years (Mattila & Pentti, 2004). It should also be noted that concrete panels exposed to outdoor climate are not equally damaged because they are exposed to wind-driven rain (WDR) differently. For instance, North facades get approximately 80% less WDR than South to West facing surfaces (Pakkala et al. 2014; Lahdensivu et al. 2013).

Finally, it should be remarked that according to several studies, the demolition of buildings does not seem to depend on the condition of buildings (as summarized in Huuhka & Lahdensivu, 2014). Rather, behavioral factors, such as economics, tenure and use nowadays are considered as decisive for demolition decisions.

2.4. Norms and design guidance: then and now

As shown above, the existing literature focuses on technical issues but takes little stance on the dimensions of panels or their suitability for new architectural design, which is in the focus of the current study. Nevertheless, some insight can be gained by looking at the evolution of construction norms and design guidance. In the 1960s and 70s, construction was guided by authorities' norms and guidelines (Mäkiö et al., 1994, p. 240). The guidelines were mostly intended for publicly subsidized buildings, but in practice, they were also adopted in privately financed production (Korpivaara-Hagman, 1984; Keiski, 1998, p. 40; Neuvonen, 2006, p. 210). In addition to the 'official' guidelines, good construction practices have been promoted in Finland since 1940s in design instructions called the RT Building Information Files. These documents are published by a non-profit organization and they are widely used in architectural education and profession.

In the 1960s and 70s, the norms only defined the minimums for floor height and room height (Mäkiö et al., 1994, p. 242). The guidelines for publicly subsidized flats gave minimum widths for two rooms: the living room and the hall (Mäkiö et al., 1994, p. 194). In addition, the RT File provided exemplary layouts for bedrooms and bathrooms but not for other rooms (Kaasalainen & Huuhka, in press). The former came in in 27 different widths and the latter in 26 different dimensions (RT 935.50; RT 936.50). Table 3 presents a summary of the aforementioned dimensions. The situation is rather similar even today, apart for the fact that the minimum floor height has increased. There still are no binding norms for room widths, but the RT Files now provide recommendations for the dimensions of all kinds of rooms. Table 4 summarizes the current requirements and guidelines. Unsurprisingly, the technical requirements for residential buildings have also changed. Table 5 presents the evolution of norms for thermal insulation and Table 6 for sound insulation.

Table 3. Norms for heights and required and/or recommended widths for different rooms in 1960–70s. Sources: Mäkiö et al. (1994); RT 935.50 (1966); RT936.50 (1965).

Building part or room	Dimension(s), mm
Floor height, minimum	2800
Room height, minimum	2500
Living room, minimum width	3300 (–1970), 3600 (1970–)
Hall, minimum width	1500
Bedroom, instructional widths	1650–4900
Bathroom, instructional dimensions	800–2800

Table 4. Norms for heights and recommended widths for different rooms in 2015. Sources: RakMK G1, 2005, p. 4–5; RT 93-10925, 2008, p. 4–7; RT 93-10926, 2008, p. 3–4; RT 93-10536, 1994; RT 93-10929, 2008, p. 6–7; RT 91-10440, 1990, p. 11–12; RT 93-10932, 2008, p.4–5; RT 93-10937, 2008, p. 3; RT 93-10945, 2008, p. 2, 4; RT 93-10950, 2008, p. 4–5; RT 93-10953, 2009, p. 3; RT 88-11018, 2011, p. 6.

Building part or room	Dimension(s), mm
Floor height, minimum for blocks of flats	3000
Room height, minimum for blocks of flats	2500
Floor height, minimum for detached and terraced houses	not defined
Room height, minimum for detached and terraced houses	2400
Bedroom (one person)	2200–3100
Bedroom (two person)	3000–4000
Living room	3600–4200
Dining room	2000–3800
Kitchen	2300–3200
Staircase (shared)	2600–2800
Staircase (private)	1800–2100
Auxiliary spaces	1800–2400

Table 5. U-values (W/m²K) in Finnish building regulation from 1969 on (Lahdensivu et al., 2015, p. 50).

Building part	1969	1974	1976	1978	1985	2003	2007	2010
Exterior wall	0.70–0.81	0.35	0.40	0.29	0.28	0.25	0.24	0.17
Roof	0.47	0.29	0.35	0.23	0.22	0.16	0.15	0.09
Base floor	0.47	0.41	0.40	0.40	0.36	0.25	0.24	0.16
Windows	-	-	2.10	2.10	2.10	1.40	1.40	1.00
Doors	-	-	0.70	0.70	0.70	1.40	1.40	1.00

Table 6. Acoustic indexes (dB) in Finnish building regulation from 1955 on (Lahdensivu et al., 2015, p. 51).

Acoustic index	1955	1960	1967	1998
Sound reduction, vertical structures	51	52	52	55
Sound reduction, horizontal structures	51	52	53	55
Impact-sound level	62	56	58	53

3. RESEARCH MATERIAL AND METHODS

The research material of the current study consists of photos of façade, plan, and section drawings of 276 blocks of flats that received public funding between 1968 and 1985. Both lamellae blocks (192 buildings) and point blocks (84 buildings) are included. Figure 7 presents a typical building and Figure 8 shows exemplary drawings. The material was collected from the archives the Housing Finance and Development Centre of Finland (ARA), which is the successor of the erstwhile funding agency for public housing. A table was created in which the types and dimensions of the structures were recorded. Their examination was conducted with SQL queries.

Figure 7. A typical precast 1970s slab block.

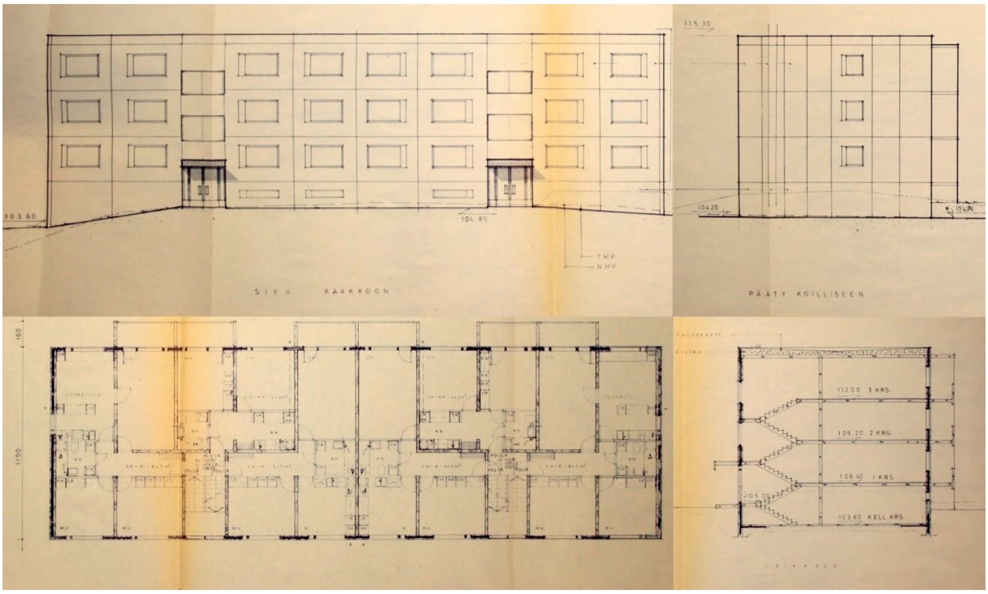

Figure 8. An example of original facade, plan, and section drawings of a building.

3.1. Quality of the research material

The set of drawings that forms the research material does not represent the building permit drawings or the final drawings of the buildings but the drawings that were used in applying public funding for the building project. The decision to collect the material from the ARA archives was based on the fact that the drawings were available from all Finnish municipalities. The data set contains buildings from 28 cities. As the examination period is renowned for fast and efficient construction, it is very unlikely that building plans would have been changed essentially after applying for the funding. Unfortunately, neither ARA nor cities store structural drawings in a consistent manner, which is why the current authors had to settle for architectural drawings only.

Some drawings had gauge lines with the dimensions of the façade panels that could be transferred to the data table, but most dimensions had to be measured from the photos. The photos were stretched to scale using some dimension given in the drawings, e.g. the height or the width of the building. This allowed measuring the panels with the precision of 0.1m. The numbers and types of panels were calculated and recorded to the data table. The numbers were calculated only for floors consisting of apartments. Attics, basements, and ground floors with secondary spaces were excluded. The reasons for the exclusion are as follows. Firstly, basements and ground floors are often in situ cast. Secondly, only a minority of the buildings has attics and basements. When these spaces exist and are precast, the panels are usually less than one meter high, which means their reusability for new purposes is very limited. Thirdly, panels of ground floors without residential spaces usually differ from the panels of the above residential floors because they are either blind or have doors and small windows to the storages and other secondary spaces. Recording them would have denoted recording a large number of singular individual panels. The exclusion does not affect the distribution of panel widths significantly, as the excluded panels do not vary in width from the panels above or below them.

The precast parts were identified by reading the drawings. Embedded texts usually list the main structures, i.e. exterior walls and intermediate floors, and elaborate on their prefabrication. Load-bearing walls (both interior and exterior) could be distinguished from non-load-bearing ones by the thickness of the wall. Facade drawings nearly always present the borders of the facade panels, and sometimes so do the plan drawings. However, it could not be identified if the load-bearing interior walls were prefabricated or in situ cast.

Similarly, the floor structures were identified from section drawings or embedded texts. There were 18 buildings for which the floor structure could not be verified. In those cases, it was assumed to be in situ cast concrete because other materials have not been used in the floors of blocks of flats during the examination period (Mäkiö et al., 1994, p. 57–62; Neuvonen, 2006, p. 153–157, 218–219). The investigation of slabs was limited to hollow-core slabs for the following reasons: First of all, the number of other prefab slab types is small in the data, although room-size solid slabs have been more common in other studies such as Mäkiö et al. (1994) and Saastamoinen (2013). Secondly, unlike hollow-core and U-slabs that were always 1200 mm wide, room-size solid slabs were manufactured in different widths and the research material does not indicate this division. Thirdly, U-slabs were quite rare and they broke easily in assembly (Hytönen & Seppänen, 2009, p. 106). They would very likely break in deconstruction, too, and therefore, they are not of interest for the current study. Very few plan drawings showed how the floor is actually divided into hollow-core slabs, but this could be deduced from the location of the load-bearing interior walls.

4. RESULTS AND DISCUSSION

4.1. Degree of prefabrication

In all, 242 or 88% of 276 buildings in the data are at least partially made of prefabricated concrete panels. The share is greater than the previous literature imply (Mäkiö et al., 1994, p. 53; Hytönen & Seppänen, 2009, p.325). The remaining 34 buildings have most often in situ cast concrete exterior walls with bricks as a cladding and in situ cast concrete slabs. When it comes to the fully or partially prefabricated buildings, ten buildings have strip panels or a mix of strip and square panels while 232 buildings (84%) represent typical panel construction with only room-size square panels. The share of square panel facades is greater in the data than in Mäkiö et. al. (1994, p. 56). 130 buildings have fully prefabricated exterior walls but in situ cast floors, while in 100, both exterior walls and floors are fully prefabricated. The share of fully prefabricated buildings in the current study (36.2%) is clearly greater than Mäkiö et al. (1994, p. 53). Even though Hankonen (1993, p. 159) has found that at least one major contractor in a major city prefabricated slabs while casting walls in situ, no such buildings were included in the data. The use of this technique was likely confined to a small geographical area.

4.2. Floor and room height

The floor height is 2800mm for all buildings in the data, and the room height depends on the thickness of the slab. 90% of hollow-core slabs are 265mm thick, which equals a room height of roughly 2500m with finished flooring. In situ cast floors range from 150mm to 250mm resulting in room heights from 2550mm to 2650mm. Most often they are 200mm thick equaling to 2600mm high rooms.

The old panels do not fulfill the current norm for floor height in blocks of flats (3000 mm) although they would conform to the room height minimum (2500 mm). In detached, semi-detached, and terraced houses, there are no norms for the floor height as long as apartments are not located on top of each other (RakMK G1, 2005, p.4–5). However, the NBCoF does not limit the number of floors in these building types. This enables reusing old panels in e.g. 3–4 floor townhouses.

4.3. Walls

83% of the buildings in the data have fully prefabricated square panel facades. On average, there are 1200 running meters of one-floor-high load-bearing facade and 3100 meters of one-floor-high non-load-bearing facade per a prefabricated building. The height of the load-bearing part of the sandwich panels as well as load-bearing interior walls depends on the thickness of the slab and ranges from 2500mm to 2650mm.

All buildings have load-bearing interior walls from concrete but it could not be verified with the data whether they are prefabricated or in situ cast. Although in situ casting is known to have been the more usual way, both techniques have been in use and can be expected to occur in the buildings of the data (Mäkiö et al., 1994, p. 66–68). The number of load-bearing interior walls is the largest when solid slab elements were used and smallest with long-spanning hollow-core slabs, i.e. BES buildings. In the latter, the number and length of load-bearing interior wall elements may be nearly half of that in the former (see Figures 1 and 2). The thickness of these walls varies from 150mm to 220mm in the 226 buildings from which the dimension could be determined. Walls that are at least 180mm thick fulfil the current requirement for partition walls that separate different apartments (Lietzén & Kylliäinen, 2014). In 47% of the studied buildings, this requirement is met. Walls thinner than 180mm can be used as partition walls inside an apartment.

4.4. Width of wall panels

Although the facades of 230 buildings were fully made of room-size square panels, the division of panels could not be determined explicitly from the drawings of 26 buildings (e.g. facade drawings had not been archived or the division of the facade was not shown in the drawings). Therefore, the final number of buildings that could be examined for panel widths and amounts is 204. In total, there are 26 287 square panels in this data that range from 800mm to 9600mm wide. 9 387 of the panels are load-bearing and 16 900 are non-load-bearing. On average, there are 129 panels per prefabricated building: 46 load-bearing and 83 non-load-bearing panels.

In all, 116 different widths were observed for panels, but some are clearly very common and some extremely rare. Load-bearing panels, i.e. usually panels on the short side of the building, show 73 different widths, 16 of which only occur in one building. Non-load-bearing panels, i.e. usually panels on the long side of the building, come in 98 different widths, 34 of which only occur in one building. In all, 20 most common panel widths cover 70% of all panels in the data; the top ten widths cover over half of the panels and the top five one third of them.

When the widths were rounded to the nearest 100mm, the number of different widths was halved to 68. Figure 9 presents a histogram of the widths and Figure 10 shows their occurrence in the buildings, distinguishing between load-bearing and non-load-bearing panels. As a rule, the occurrence of most common widths is more frequent than their share of all panels. For example, the most common panel width for non-load-bearing panels, 3000mm, covers less than 10% of all panels but occurs in every third building.

The modular arrangement of BES and the lack of that in the earlier panel systems appear to show in the figures. In BES, the modular pitch was 1200mm for load-bearing structures, and there is, indeed, a clear peak for 2400mm wide load-bearing panels in Figure 9. Similarly, there are notable peaks for non-load-bearing panels (between 3000mm and 4500mm and for 6000mm) that follow the 300mm modular pitch of BES for adjoining structures in horizontal direction.

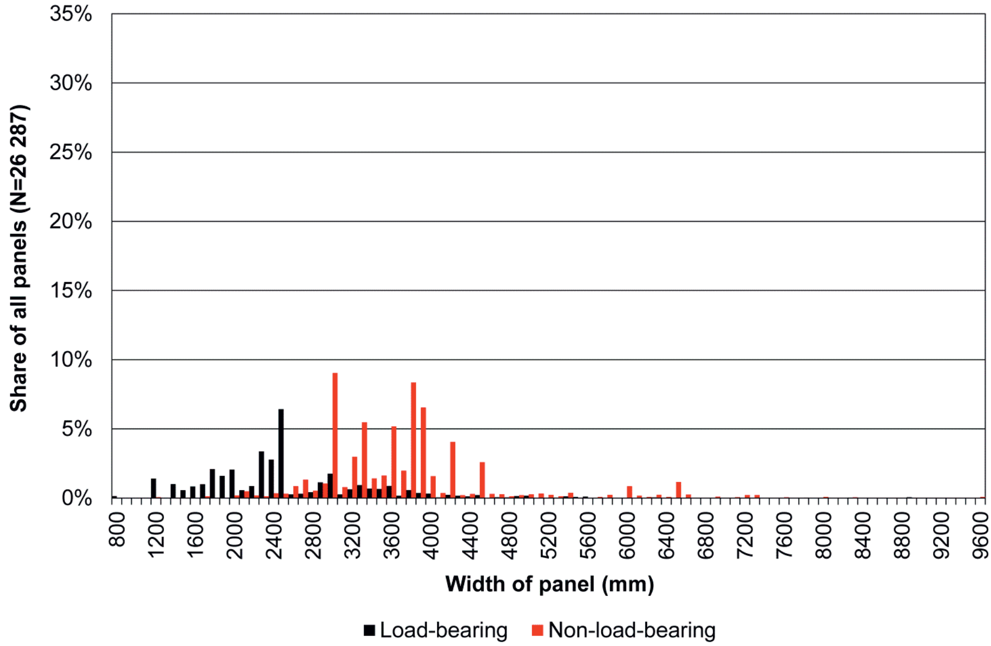

Figure 9. Width distribution of panels (N=26 287 panels).

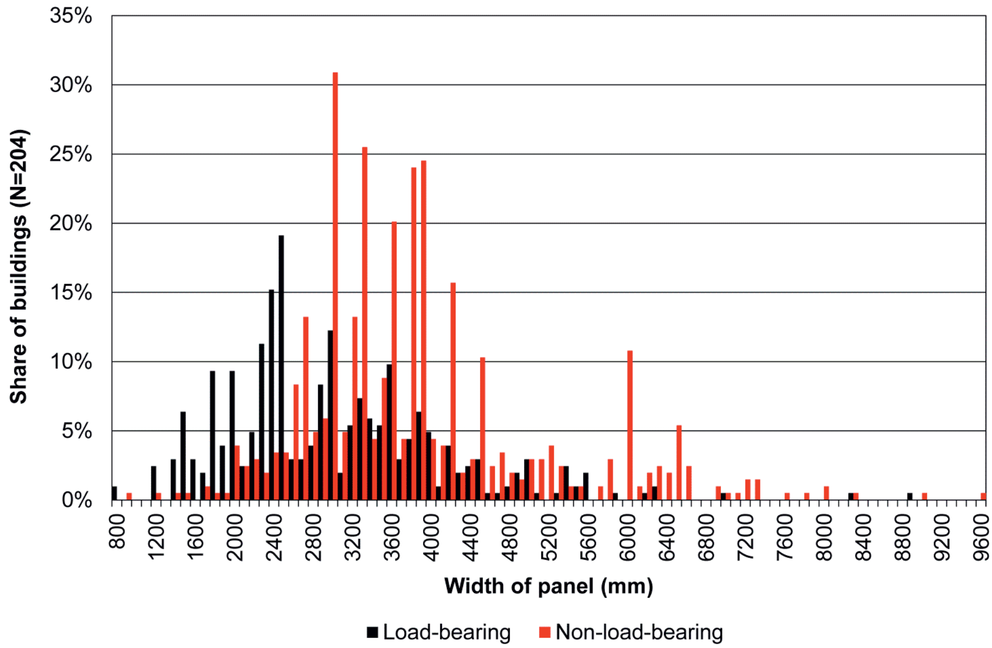

Figure 10. Occurrence of the widths in the in buildings (N=204 buildings).

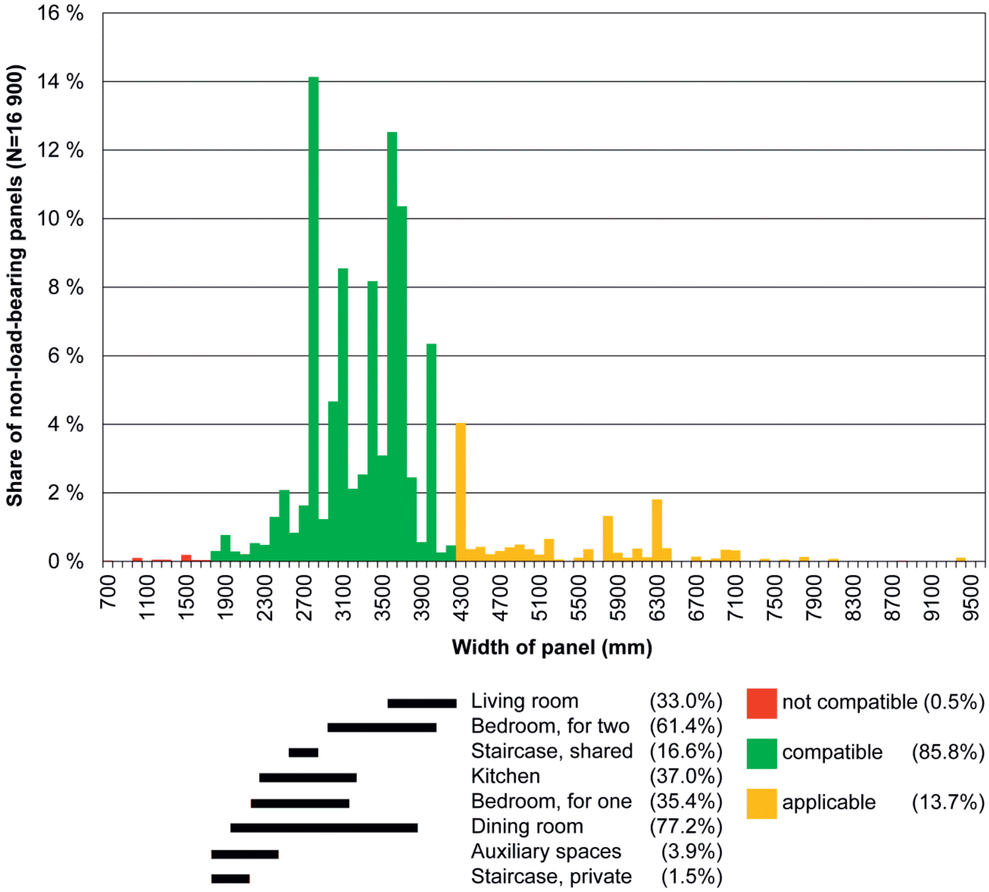

Figure 11. Compatibility of non-load-bearing panels to currently recommended dimensions for different rooms (N=16 900 panels).

Like Mäkiö et al. (1994, p. 66–68; 82–84) imply, load-bearing panels are generally shorter than non-load bearing panels, i.e. less than a room wide. The load-bearing façade of a room is typically put together from two or more panels. Therefore, only non-load-bearing panels were studied for the compatibility with current recommendations for room widths. 150mm was reduced from the panel dimension to acknowledge the loss of width resulting from the connections with crosswalls. As seen in Figure 11, only 0.5 of all non-load-bearing panels are not wide enough in the light of the present recommendations. 85.8% comply directly with the recommendations to one or more rooms, and 13.7% are wider than recommended and, thus, applicable as well. When it comes to the main rooms of a flat, the majority of panels are compatible with two-person bedrooms and dining rooms, while circa one-third of panels are appropriate for living rooms, kitchens, and one-person bedrooms. It should be noted that a loss of width from possible external connectors and their casing (Saastamoinen, 2013, p. 96) was not considered in Figure 11, but it would hardly exceed 100mm.

4.5. Types of wall panels

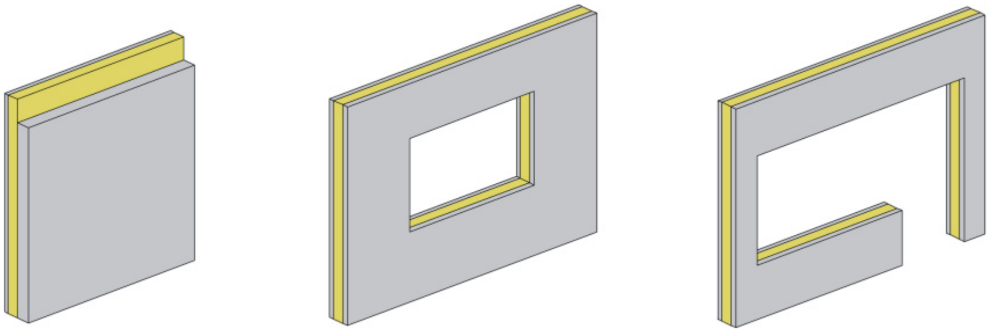

Figure 12. Main panel types from left to right: blind load-bearing panel; typical non-load bearing panel with a normal window, non-load-bearing balcony back wall panel.

Figure 12 shows the three main types of panels in the data. Figure 13 shows the overall amounts of panels of different types and Figure 14 presents the numbers of panels with individual type and width. Load-bearing panels are most often blind. Non-load-bearing panels nearly always have a window; or a window and a door if they are balcony back walls. Figure 15 shows the width and type distribution for load-bearing panels, and Figure 16 shows how often they occur in the buildings of the data. Figures 17 and 18 present the same figures for non-load-bearing panels. Although the number of individual panels can be expected to grow with the increase of the sample size, the results indicate a strong repetitive nature. For example, as little as 20 most common individual panels cover 50% of all panels in the data, and the 10 most common individual panels in each type cover as much as 64–83% of the panels in that type.

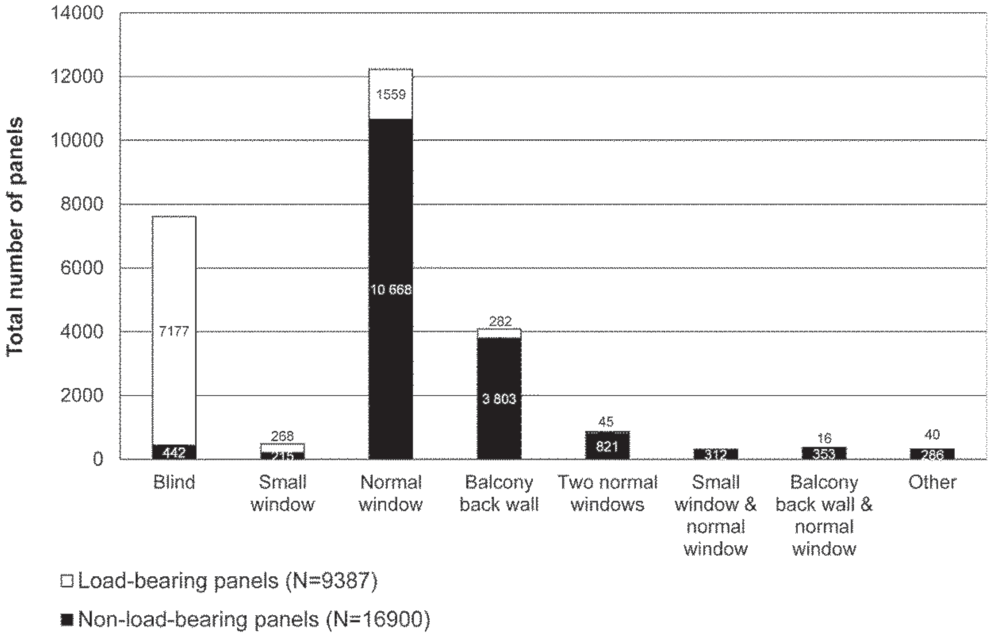

Figure 13. Total numbers of panels for different panel types (N= 26 287 panels). 'Other' includes rare types such as two-room wide panels with three windows, panels with Juliet balconies, etc.

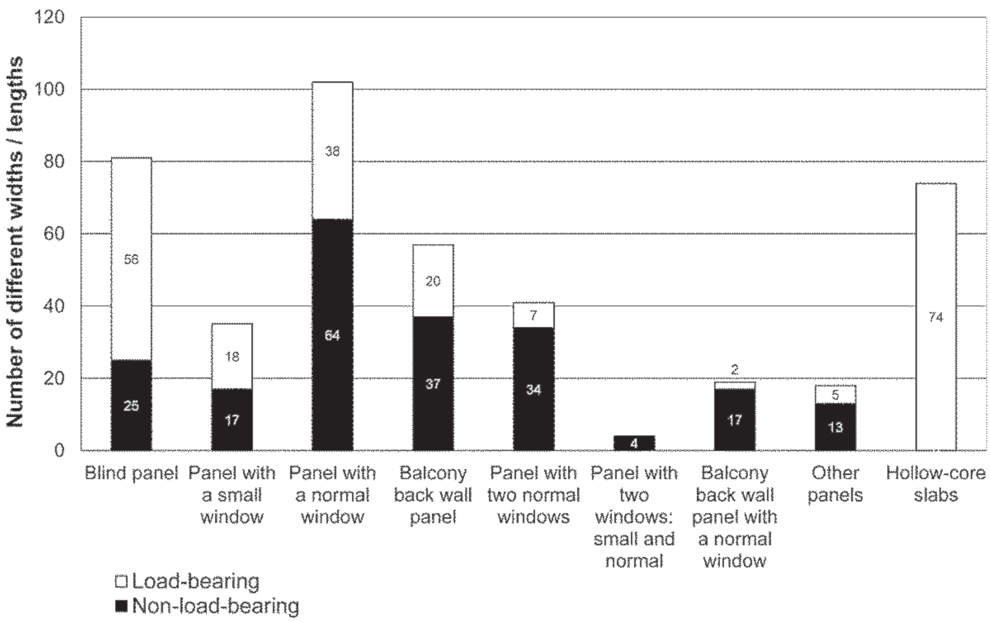

Figure 14. Numbers of individual widths for different panel types (N=431 width-type combinations).

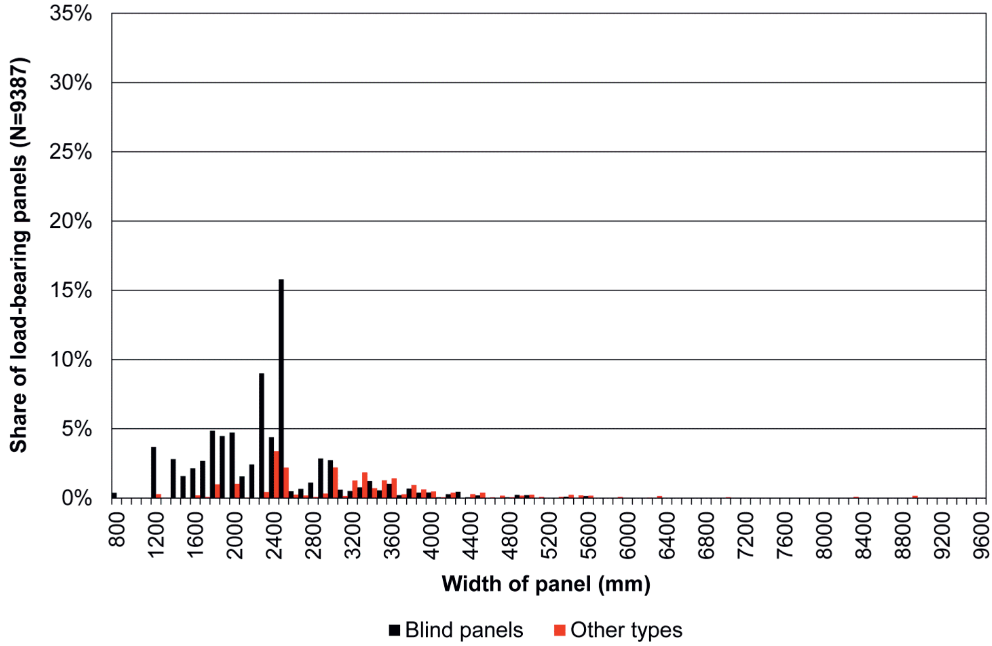

Figure 15. Width distribution of load-bearing panels according to the type (N=9 387 panels).

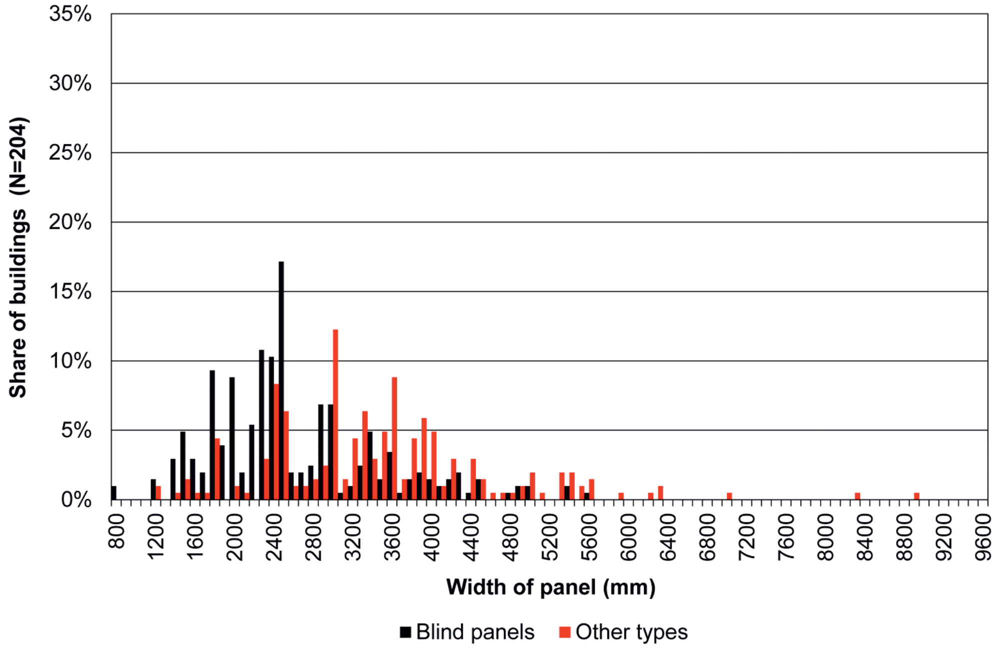

Figure 16. Occurrence of the load-bearing panels in the buildings (N=204 buildings).

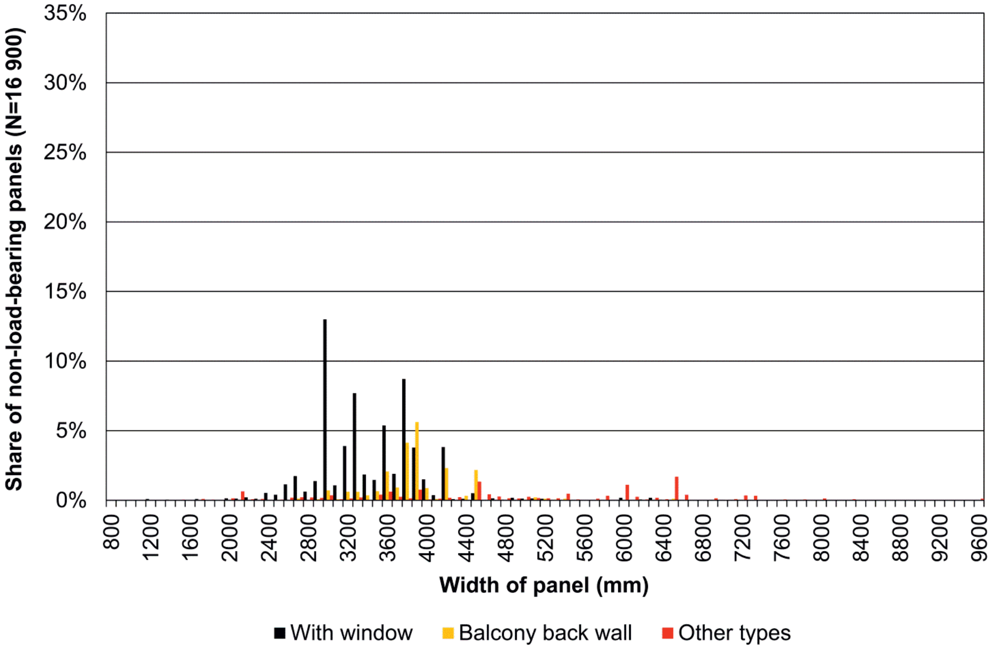

Figure 17. Width distribution of non-load-bearing panels according to the type (N=16 900 panels).

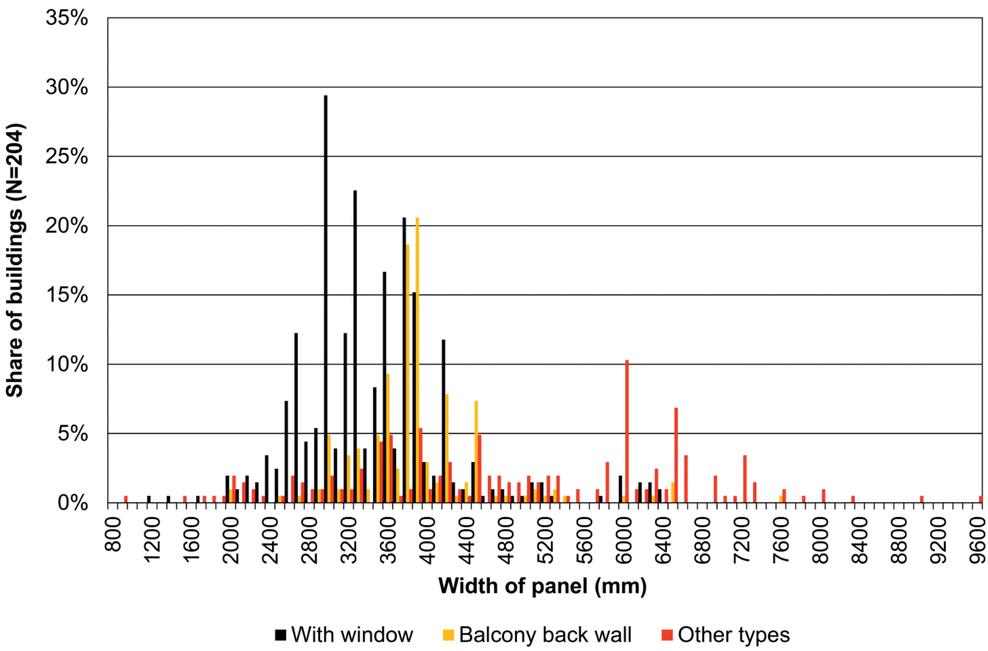

Figure 18. Occurrence of the non-load-bearing panels in the buildings (N=204 buildings).

4.6. Composition of facades

The minimum number of different types of panels that occurred in one fully prefabricated building is three and the maximum 18. Buildings do not usually have more than six different panels: one or two individual load-bearing panels and two to four individual non-load-bearing panels. The most typical building is one with one load-bearing panel and three different non-load-bearing panels. Figure 19 shows the numbers of panels in the buildings of the data.

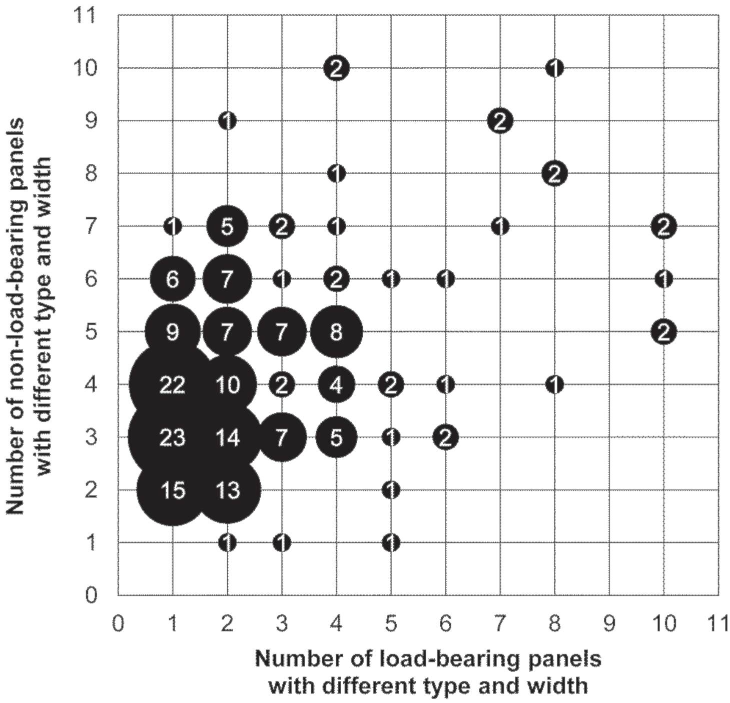

Figure 19. Number of buildings with different number of panels (N=204 buildings).

4.7. Thermal insulation of wall panels

In the vast majority of panels, the designed thickness of thermal insulation is 120mm of mineral wool. Typically, the actualized amount is smaller than that due to the insulation having compressed circa 10mm in the casting of the panel (Lahdensivu, 2012). The insulation equals to a U-value of 0.40 W/m²K, which does not comply with the present-day norm, 0.17 W/m²K (RakMK C4, 2003). The required U-value can be achieved by adding 150mm of new insulation on the surface of the reused panels. Because additional insulation prevents moisture from entering the concrete, corrosion and frost damage, which are common phenomena in old panels (Lahdensivu et al., 2011 & 2013; Lahdensivu, 2012), can be brought to halt as well. Due to the need to add insulation, the surface type of a panel has little significance for reuse, although it has been found to affect the panel's durability properties (Lahdensivu, 2012). Only if a panel would be reused in a cold or a semi-warm structure without adding any new cladding, would the durability properties play a greater role. In that case, the knowledge on the exposure conditions and different durability properties of surface types presented in Lahdensivu (2012) could be used for evaluating which panels to select for reuse. However, a review of the existing reuse projects shows that this kind of usage is very rare, likely due to architectural reasons (Huuhka, 2010a).

4.8. Slabs

In comparison to wall panels, floors have smaller potential for reuse due to the fact that in the data, 64% of them are in situ cast. Of the 100 fully prefabricated buildings in the data, 75 (27% of all buildings) have 1200mm wide hollow-core slabs; 15 (5% of all buildings) have room-size solid prefabricated concrete slabs; and 10 (4% of all buildings) have 1200m wide U-slabs. The share of solid slabs is much smaller in this study than in Mäkiö et al. (1994) or Saastamoinen (2013), while the share of in situ cast floors is larger than in the literature.

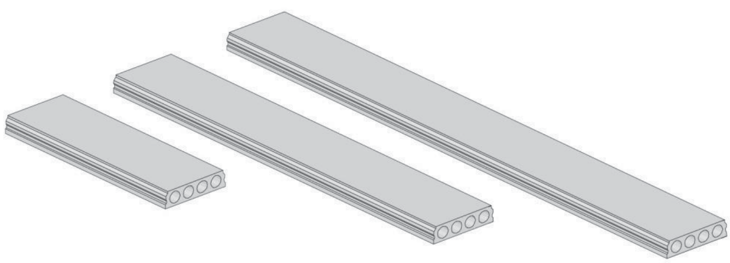

Figure 20. Typical hollow-core slabs: one, two or three rooms long.

On average, there are 1410 m² of hollow-core slab floor per a building, or 180 slabs. Due to typical apartment layouts in the plans, the slabs come in the lengths of one, two or three rooms (Figure 20). In all, there are 74 different lengths that range from 2400mm to 10800mm, or 68 lengths when rounded to the nearest 100mm. Figure 21 shows a histogram about the length distribution and Figure 22 lists the occurrence of the lengths in the buildings of the data. Unsurprisingly, the slab lengths are connected to the panel widths. For example, the most common slab length, 6000mm, is compatible with two panels of the most common width, 3000mm. This study does not consider the possible incompatibility situations that may result if the slabs are shortened in diamond sawing as suggested by Saastamoinen (2013, p. 108).

In 90% of the cases, the thickness of the hollow-core slab was 265mm, which is in line with previous findings such as Mäkiö et al. (1994). Due to the tightening of the norms for impact sound insulation in 1998, the 265mm slab is no longer usable as a floor separating different apartments from each other (Lietzén & Kylliäinen, 2014). It can only be utilized within apartments.

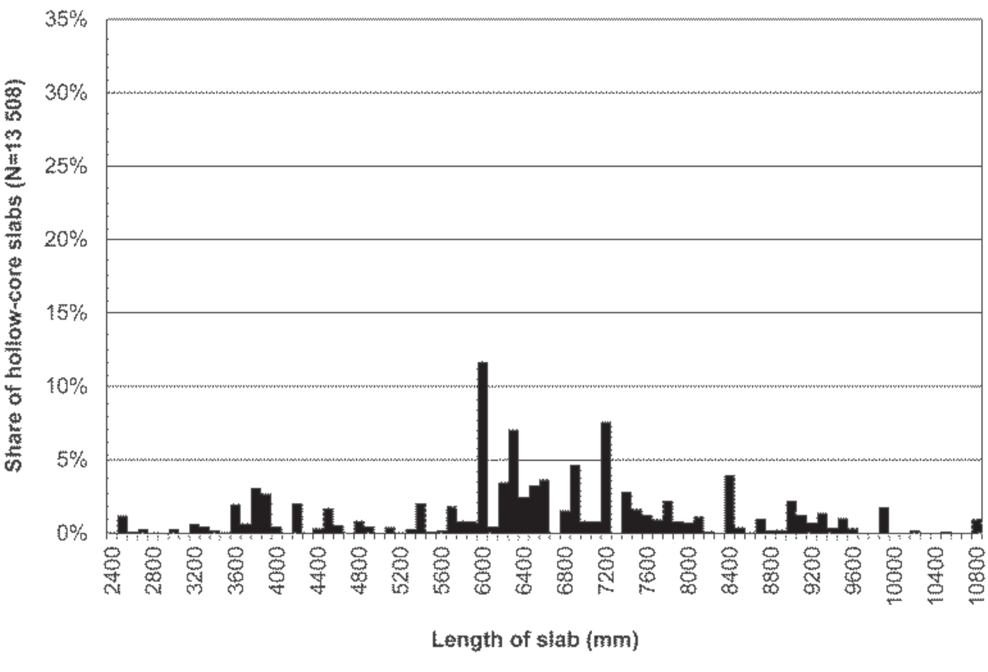

Figure 21. Length distribution of hollow-core slabs (N=13 508 slabs).

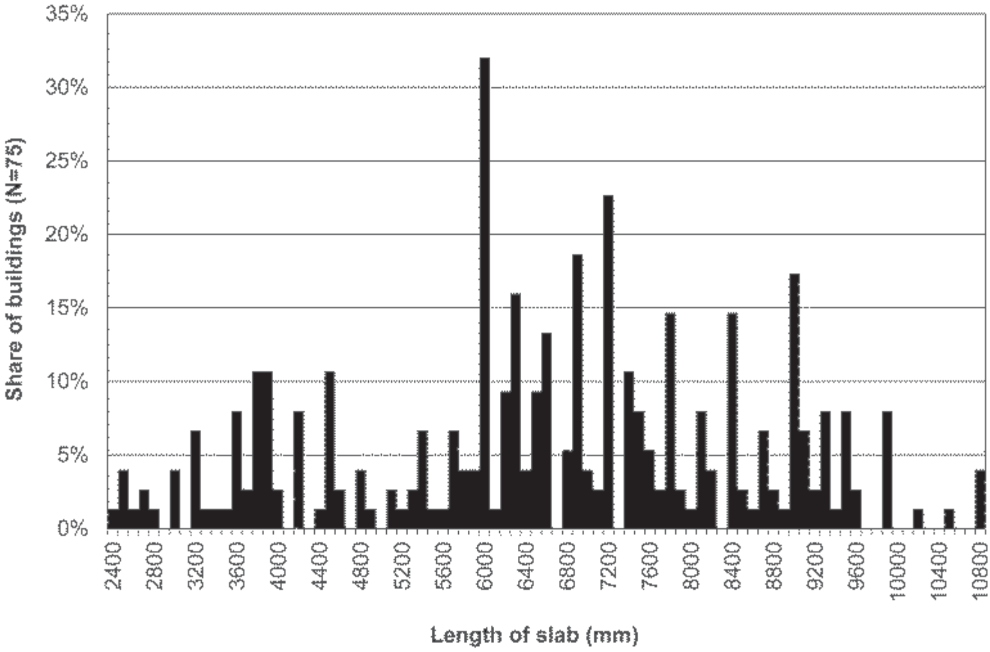

Figure 22. Occurrence of the lengths in the in buildings (N=75 buildings).

5. GENERALIZABILITY OF THE RESULTS

5.1. Difference between public-funded and privately financed housing production

During the examination period (1968–1985), 42% of new flats were publicly funded, the rest naturally being privately financed (Laine, 1993; Kakko, 2011, p. 120–121). As the research material of this study consists solely of publicly financed projects, it is important to consider whether they display differences to privately funded apartment blocks. Keiski (1998, p.40) and Neuvonen (2006, p. 210) have found that the instructions for public housing were adopted in privately financed construction as well. Mäkiö et al. (1994, p. 46) state that the difference between privately and publicly financed construction was often only in the materials, and Neuvonen (2006, p. 210) takes the statement even further by specifying that the difference could be as minor as the finishing materials. In addition, Neuvonen (2006, p. 180) states that the widespread use of modular grid in plan design also promoted the uniformity of dimensions between different buildings and constructors regardless of the financing method. Based on these assertions, it can be expected that the financing method does not make a major difference in the use or properties of prefabricated components. Therefore, with regard to the scope of this study, the results obtained by studying publicly financed buildings can be expected to apply well to all apartment blocks of the era.

When it comes to the prefabricated components per se, the correspondence between the research material and the prefabricated building stock in general can be evaluated by applying two of the original research questions to both groups: what are the prefabricated parts—their structure and distribution—and what are their possibly recurring dimensions. As there is no all-encompassing database on such parts, the largest comparable sample is Mäkiö et al. (1994), which consists of 270 randomly selected apartment blocks from the years 1960–1975 in Helsinki. Mäkiö et al. (1994, p. 36) remark that the timing of the shift to prefabricated construction varied geographically. Based on the current paper's research material, which consists of buildings from all over the country, there is no reason to believe that the location has had any significant effect on the buildings themselves. Table 7 presents the distribution of facade panel types and structures in this study and in Mäkiö et al. (1994). The sample sizes are very similar, but due to the difference in studied years, a direct comparison can only be performed for a limited year range. The differences between the full ranges can, however, be used for examining trend changes.

In both studies, the degree of prefabrication rises considerably towards the ends of the studied time periods. A similar shift occurs with the frame types, as the concrete crosswall frame becomes more common towards the 1970s, replacing other types such as brick walls or in situ cast concrete frames (Mäkiö et al., 1994). Considering the convergence the two studies have—and that BES-buildings, which are prefabricated and use a crosswall frame, started to take over in late 1970s (Mäkiö et al., 1994, p. 68)—it appears that the differences would be likely to even decrease after 1975.

Table 7. Comparison of structures between research material and Mäkiö et al. (1994).

	Research Material		**Mäkiö et al. (1994)**	
Number of compared buildings	276 / 101		270	
Partially or fully prefabricated facades, % of all buildings	(1968-1985) 87.7%		(1960-1975) 61.2%	
Partially or fully prefabricated facades, % of all buildings, 1970-1975	80.2%		87.8%	
Crosswall frame, % of all studied buildings	(1968-1985) 90.9%		(1960-1975) 61.1%	
Crosswall frame, % of all studied buildings, 1970-1975	90.1%		84.4%	
Structure, non-load-bearing façade:				
Number of compared buildings*	275 / 101		270 / 122	
Concrete sandwich, %	(1968-1985) 88.0%		(1960-1975) 74.3%	
Concrete sandwich, % 1970-1975	80.2%		91.0%	
Structure, load-bearing façade:				
Number of compared buildings*	272 / 101		270 / 119	
Concrete sandwich, %	(1968-1985) 85.7%		(1960-1975) 84.5%	
Concrete sandwich, % 1970-1975	77.2%		93.7%	
Distribution of panel types, prefabricated non-load-bearing façade:				
Number of compared buildings*	242 / 82		270 / 122	
Distribution of panel types	Square	Strip	Square	Strip
% of buildings, all studied buildings	95.8%	0.4%	70.6%	29.4%
% of buildings, 1970-1975	96.3%	1.2%	90.5%	9.5%
% of m² built, 1970-1975	97.0%	3.0%	91.0%	9.0%

* Buildings where the relevant information could be determined from the research material.

As for facade panels, the following comparison with Mäkiö et al. (1994) has been limited to buildings with crosswall frames because they constitute the overwhelming majority and the study covers them best. In both studies, concrete sandwich is by far the most common panel structure on both load-bearing and non-load-bearing facades. The share of concrete sandwiches increases in both studies towards the ends of the examination periods. The distribution of panel types on non-load-bearing facades (as strip panels do not occur on load-bearing facades) is heavily weighted towards square panels in both data. A similar shift in shares is seen in the distribution of panel types. Looking at both studies, it becomes clear why Mäkiö et al. (1994, p. 52) regard a building with a crosswall frame and facades with square panels as the typical Finnish apartment block for 1960–1975, though it appears that this statement can be extended beyond the year 1975.

Table 8 presents the distribution of the most common prefabricated floor structures in the research material of the current paper. Of these, the hollow core slab is clearly in the majority, increasing notably for the last five of the studied years. Mäkiö et al. (1994) do not present actual numbers on the distribution of different floor types over the years, but the general trends appear as similar to the current study with in situ cast floors dominating the 1960s and the early 1970s before giving way to prefabricated solid slabs and hollow-core slabs. The dominance of the hollow-core slab coincides with the statements by Mäkiö et al. (1994, p. 41) and Neuvonen (2006, p. 218), both of which mention this slab type as eventually becoming the most common choice.

Table 8. Distribution of the most common floor structures in the research material.

Year range	1968-1985	1968-1975	1976-1980	1981-1985
Prefabricated floors, % of all*	36.2%	15.5%	41.7%	71.4%
Hollow core slab, % of all*	27.2%	10.1%	26.2%	63.5%
Hollow core slab, % of all prefabricated	75.0%	65.0%	62.9%	88.9%
Solid precast floor panels, % of all*	5.4%	4.7%	9.5%	1.6%
Solid precast floor panels, % of all prefabricated	15.0%	30.0%	22.9%	2.2%

All in all, based on the comparison with Mäkiö et al. (1994) and the various descriptions of contemporary construction in literature, the structures in the research material appear to correspond closely to the general stock of similar buildings at that time. Although a year range for a direct comparison with Mäkiö et al. (1994) is somewhat limited, the decrease in diversity towards the end of that time frame suggests even greater uniformity for the later years.

Due to such data not being available for the general building stock, considering the actual dimensions of the panels is limited to comparing the research material's measurements to more general statements found in literature. The heights of square panels are determined by the minimum floor height and therefore, they are not likely to have any variation regardless of the sample. This height is, according to the research material as well as Mäkiö et al. (1994), 2800mm. The thicknesses of the panels are dictated by structural requirements and therefore, they should not vary significantly by sample, either. This leaves the width of the panels as the main dimension to consider. As the width of a non-load-bearing facade panel depends on the distance between the load-bearing walls it is suspended from or propped against, the dimension should be one or more rooms wide. In addition, due to the widespread use of modular coordination, this dimension should most often be multiples of 300mm. As shown in Tables 1 and 2, Mäkiö et al. (1994, p. 78, 82) state that the panel width is 3.0–3.9 m in case of one-room panels or 6.0–7.2 m in case of two-room panels, and most commonly 3.3–3.6 m. Figures 9 and 11 show the width distribution of non-load-bearing facade panels in the research material. 55.6% of the panels in the research material were between 3.0m–3.9m and 3.5% between 6.0m–7.2m, totaling up to 59.1%. 21.1% of the panel widths landed in the range of 3.3m–3.6 m. 58.0% of panel widths were multiples of the 300mm module, with 3.0m, 3.9m and 3.3m being the most common in a respective order. Overall, the dimensions of the panels fit the ranges given in Mäkiö et al. (1994). This shows as clear peaks in Figures 9 and 11 in one-room width and, to a much smaller extent, in two-room width. As stated previously, the figures also show the prevalence of 300mm module.

5.2. An estimation of resources embedded in the apartment building stock

In all, 30 378 multi-story apartment buildings were built in Finland between 1960 and 1989. This represents 52% of the stock. During the most representative decade with regard to the year range of this study, the 1970s, 12 652 apartment blocks, i.e. 22% of the stock, were erected. (Statistics Finland, 2013). The following calculation intends to give a rough estimate about the panel and slab resources embedded in this stock. If a 95% share of prefabricated facades and a 27% share of hollow-core slab floors are assumed, over 12 000 1970s buildings would have prefabricated facades and 3400 would have hollow-core slab floors. If the average amounts of panels are taken as such, this stock would contain over 500 000 load-bearing panels, over 900 000 non-load-bearing panels and over 600 000 slabs (or 5.3 million m^2 of floor). If these figures are extended to include the previous and the following decade, the numbers are as follows: nearly 2 200 000 non-load-bearing panels, over 1 200 000 load-bearing panels and over 1 400 000 slabs (or nearly 12.9 million m^2 of floor). The true numbers will be lower, because the degree of prefabrication was not as high in the beginning of the 1960s, although it kept rising the whole of 1980s until the mid-1990s (Hytönen & Seppänen, 2009, p. 325).

There are several norms that currently prohibit the use of reclaimed concrete panels in erecting new blocks of flats in Finland. These include requirements for floor height and acoustic properties of walls and slabs that separate apartments. However, these factors do not delimit the reuse of panels in the design of detached houses, which in 2013 represented a notable share of 34% of all residential building production in Finland. Between 2000 and 2013, an average of 12 300 detached houses with 2 160 000 m² were built annually. Thus, the average area of a new detached house was 175 m². (Statistics Finland, 2013). When the average gross floor area of an apartment block is 1570m², a condemned building could possibly contribute to the structures of up to nine detached houses. Therefore, the 1970s apartment building stock could be seen as a reserve of components for nearly 108 000 detached houses (the building needs of nearly nine years at the current pace), and if the previous and following decades are considered similarly, up to 260 000 houses (the needs of 21 years). Of course, the calculation is very rough and does not take into consideration possible damage that could occur in the old structures or during deconstruction. However, it does give an indication of the magnitude of this reserve, which is to be considered remarkable.

6. CONCLUSIONS

The study has been conducted with an extensive data set that represents well Finnish multi-story housing construction between 1968 and 1985. With regard to the size of the stock, the degree of prefabrication and the dimensions of the panels and slabs, the mass housing of the time represents a notable reserve for building components. There are, however, fewer slabs available than wall panels, as the majority of floors were in situ cast. Only a fraction (0.5%) of the panels are clearly incompatible with current recommendations for room widths. As norms related to floor height and acoustics do not allow using most of the elements in new multi-family housing, the use would be limited to detached houses. These form one-third of all apartments erected in Finland annually. The magnitude of the component reserve is roughly ten to 20 times the annual housing construction in this building type.

Although plans of apartment buildings were never standardized in Finland, the inventory of elements recognized in this study shows that the dimensions of panels and slabs are highly uniform. To this end, Finnish precast construction does not come across more variable than, for example, the fully standardized German panel systems (for those, see e.g. Mettke, 2003 & 2007). While standardization of buildings was not an aim in developing the BES system, it was clearly already embedded in the corporate culture of the building industry. Even though 357 individual panels were recognized in the current study when the type and width were considered, one building usually has only two to six individual panels. In fact, the 20 most common individual panels cover 50% of all panels in the data, and the 10 most common individual panels in each type cover as much as 64–83% of the panels of the type. In addition, the most common dimensions and individual panels typically occur more frequently in the buildings of the data than what is their relative frequency of the panels of the data. For example, the most common panel width covers less than 10% of all widths but is found in every third building.

The elements from one average-sized apartment building could make up to nine detached houses. Although a number of structural details were in use, which resulted in discrepancies in the vertical dimensioning of panels, this has little significance because panels and slabs from a single building are, of course, compatible with each other. The inventories of typical dimensions of components collected hereby provide a starting point for conceptualizing new housing from reclaimed elements. As neither architects nor their clients would likely want to reuse old apartment plans, new plan design from old elements should be the subject of a new study.

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