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Building ’Post-Growth’

Quantifying and Characterizing Resources in the Building Stock

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Abstract

Building stocks will play growing roles in the extraction of secondary construction materials in future. Moreover, as there is a need to decouple buildings' service provision from their material consumption, building stocks should, in fact, be considered not only as deposits of raw materials but also as reserves of space. Despite of their significance, these stocks tend neither to be well known nor systematically analysed. The end-of-life phase of buildings is especially poorly covered in research, although the aspects of buildings' mortality and survival are fundamentally intertwined. The omission is highly problematic, because it precludes understanding the fundamental dynamics of the stock.

The current study is situated in Finland, where the basic composition of the stock is relatively well established in the Building and Dwelling Register, contrary to many other countries. Taking advantage of statistical description, this dissertation explores the geography and characteristics of obsolete parts of the Finnish building stock, that is, demolished and problematically vacant buildings. The dynamics, or the relations, within the stock are also considered on a very basic level, with the help of a simple correlation analysis. In order to exemplify refining the results of this kind of top-down research, the study then switches to a bottom-up approach and zooms into the more specific composition of a selected age-use cohort, the 1960–80s blocks of flats. The types and dimensions of the cohort's components, or concrete panels, are inventoried, and the results are compared to the current requirements for dimensioning living spaces. Furthermore, the spatial configurations of flats, the service provided by these physical structures, are also investigated using graph theory informed typological methodology. The findings consist of a typology of flats characteristic to the cohort. Lastly, the extents of the reserves in the entire stock of demolished buildings, the stock of problematically vacant residential buildings and the exemplary cohort (its existing, vacant and demolished parts) are quantified and proportioned to each other and new construction, inter alia.

By highlighting the magnitudes of secondary deposits of materials, components and spaces, this dissertation suggests that public policy should start paying more attention to the building stock and the potentials embedded within it. Even though an unambiguous relation between vacancy and demolition was not identified, the key finding from the resource perspective is that significant amounts of obsolete buildings are geographically concentrated on cities. In order to practice sustainable policies on the building stock, planners and decision-makers should be better aware of these reserves and acknowledge their adaptation and modification capacities.

Preface

The building stock is banal, utterly mundane. It is something everyone has an intuitive understanding of, and therefore, it is all too easy to simply shrug off. In reality, there is surprisingly little researched and generalizable knowledge about the stock. This remark applies to existing buildings, buildings that once existed but have since vanished, as well as forces influencing and driving such changes in the stock. Even though a research object as large as the entire building stock may seem challenging to study, the real challenge is recognizing 'knowing' from knowing.

During this dissertation process, the School of Architecture in Tampere University of Technology (TUT) has been my home base. Starting from August 2012, I have had the privilege to conduct my research on a four-year funding from the Doctoral Programme of TUT's President, which has guaranteed me a baseline of academic freedom. My work has also been supported by the Finnish Foundation for Technology Promotion TES in the form of a personal grant and the Ministry of the Environment, the Housing Finance and Development Centre of Finland and Ekokem Corporation in the form of project funding that has enabled me to purchase and arrange the collection of research data. The Ministry of the Environment and Ekokem Corporation funded project 'ReUSE' (Repetitive Utilization of Structural Elements) and the Housing Finance and Development Centre of Finland supported project 'MuutosMallit' (Modification Models for Mass Housing Blocks and Flats).

I wish to thank my departmental supervisors, professors Kari Salonen (2010–13) and Ari Hynynen (2013–16) for seeing over the progress of my doctoral studies. I also thank Kari Salonen for talking me into postgraduate studies: this took place already prior to I finalized my master's thesis in 2010. Furthermore, I am thankful for senior lecturer Harri Hagan, who made me interested in existing buildings in the first place. In addition to the support I have received in the School of Architecture, I am most grateful for having received Dr. Jukka Lahdensivu from the research group 'Service Life Engineering of Structures', based in the Department of Civil Engineering, as my instructor. My heartfelt thanks go out to Jukka for having been an emphatic and actively participating mentor. I believe my chances to make it would have been much slimmer without his support.

In addition, I wish to acknowledge the significance of the following persons and thank them for their help and support: the pre-examiners of my dissertation, Prof. André Thomsen from Delft University of Technology and Prof. Niklaus Kohler from Karlsruhe Institute of Technology; my opponent, Dr. Minna Sunikka-Blank from University of

Cambridge; the editors of the journals I have published in, in particular Mr. Richard Lorch from Building Research and Information; the anonymous reviewers that invested their time in assessing my manuscripts and helped me to improve them; the steering group members of the aforementioned research projects that I have worked for; my co-authors Tapio Kaasalainen and Jani Hakanen; my peers Iida Kalakoski, Sini Saarimaa, Tuomo Hirvonen, Anna Helamaa, Jenni Poutanen, Noora Pihlajarinne, Sanna Peltoniemi and Tuomo Joensuu in the School of Architecture and Petri Annila, Kimmo Hilliaho, Arto Köliö, Toni Pakkala, Antti Kurvinen, Jaakko Vihola and Jussa Pikkuvirta in the Department of Civil Engineering; my research assistant Hanna Achrén, who participated in the collection and processing of some of my research material together with my aforementioned co-authors Tapio and Jani; as well as faculty members that have offered me support in one form or another during this process: Dr. Pekka Passinmäki, Prof. Olli-Paavo Koponen, Ms. Maria Pesonen and Mr. Ari Rahikainen. I also wish to thank my parents Marjut and Paavo for encouraging me to study from an early age.

The most important thanks go out to my beloved husband Petri Haukka, who has provided me with a loving and kind home environment that has been tolerant towards extensive working hours as well as working during evenings, weekends and holidays. There may not be a man behind every successful woman, but there sure has been one behind me. For that, I thank you with all my heart.

Hämeenlinna, 8th September 2016

Satu Huuhka

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Appendixes

Articles

Abbreviations

ARA	Housing Finance and Development Centre of Finland
BDR	Building and Dwelling Register
C&D	Construction and demolition
EC	European Commission
EU	European Union
GIS	Geographical Information System
HVAC	Heating, ventilation, air conditioning
LCA	Life cycle assessment
n.e.c.	Not elsewhere classified
NRB	Non-residential buildings
MFA	Material flow analysis
OSF	Official Statistics of Finland
PIS	Population Information System
RB	Residential buildings
rm	Running metres
RT	Building information
s.d.	Standard deviation
TTKK	Tampere University of Technology (previous Finnish abbreviation)
TTY	Tampere University of Technology (current Finnish abbreviation)
TUT	Tampere University of Technology
VTT	VTT Technical Research Centre of Finland

Glossary

Adaptive reuse	Changing the intended usage of a building, *e.g.* from industrial to residential
Building stock	All buildings standing at a given time
Cohort	Category of buildings in the stock, characterized by the building type (use cohort), the construction decade (age cohort) or both
Component reuse	Reuse of building parts in construction, usually following deconstruction
Conversion	See 'adaptive reuse'
Deconstruction	Non-destructive disassembly of building parts, usually a prerequisite for component reuse
Demolition	Destructive removal of a building or a part of it
Dynamics / dynamic behaviour	Pattern or process of change
Existing stock	See 'building stock'
Home	Unit intended for the use of one household regardless of the building type, *e.g.* a flat, a terraced house or a detached house
Home modification	Adaptation of a home for changed housing needs, *e.g.* the needs of the elderly, without changing the intended usage of the building (*cf.* adaptive reuse)
Housing stock	Stock of residential buildings, *i.e.* the building stock without non-residential buildings
Flat type	Stereotypical flat plan, derived from a large number of cases; a flat type includes the basic shape and room arrangement of the flat as well as its rough size

Graph theory	Branch of mathematics that models pairwise relations between objects
Mortality	Buildings' quality of being susceptible to 'death' *i.e.* destruction or demolition
Obsolescence	Outdatedness, the process of ceasing to be in use and useful
Post-growth	Approach aiming at acknowledging the limits to infinite economic growth set by the physical constraints of a planet with finite resources
Residential building	Domestic building intended for residential use, such as a detached, semi-detached or terraced house or a block of flats
Non-residential building	Non-domestic buildings or a domestic building not intended for residential use
Normal vacancy	Vacancy that is not 'problematic' (see below)
Problematic vacancy	In multi-family buildings, ≥10% of homes vacant for more than six months; in detached houses, vacancy exceeding two years
Replacement rate	Demolished buildings or floor area per built buildings or floor area
Resilience	Systems' ability to adapt to changed conditions
Survival	Buildings' capability to escape 'mortality'
Typical flat	Flat that corresponds to a certain flat type
Typology	Classification based on types, *i.e.* categories that share given features; in architecture, the shared features are forms and shapes
Vacant / unoccupied home	Home intended for permanent residence that has no persons registered as residing there; the information is included in the Finnish BDR

List of publications

I. Huuhka, S. & Lahdensivu, J. (2016). Statistical and geographical study on demolished buildings. *Building Research and Information, 44*, 73–96.
II. Huuhka, S. (2015). Vacant residential buildings as potential reserves: a geographical and statistical study. *Building Research and Information*, advance online publication.
III. 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*, 105–21.
IV. Kaasalainen, T. & Huuhka, S. (2016). Homogenous homes of Finland: 'standard' flats in non-standardized blocks. *Building Research and Information, 44*, 229–47.

In Article I, Jukka Lahdensivu has written the majority of Chapter 2.3. I have accounted for the rest of the article.

In Article III, Tapio Kaasalainen and Jani Hakanen have been responsible for collecting and processing the raw data. Tapio Kaasalainen has also written Chapter 5.1. Jukka Lahdensivu has written Chapter 2.3. I have accounted for the research design; analyzing the data; writing the Introduction, Background (Chapter 2.3 excluded), Results, Discussion (Chapter 5.1 excluded) and Conclusions; and for editing the paper.

In Article IV, Tapio Kaasalainen has been responsible for collecting, processing and analyzing the data and for writing the majority of chapters Research material and methods, Results and Discussion. I have been responsible for the research design, and for writing the Introduction, Background and Conclusions. I have also participated in writing the other chapters and edited the paper.

The articles have not been included in a dissertation prior to this one.

1 Introduction

During the 20th century, Finland's development was characterized by growth: the industrialization, modernization and urbanization of the country reached simultaneously their climaxes less than 50 years ago. In the construction sector of a growth-oriented society, research and development activities focus naturally on new buildings, their technology and architecture. Today, however, the building stock of Finland, like those of most European countries, is already 'mature' or 'saturated'. This is to say that the annual renewal rate of the stock is minor, around only 1% (Hassler, 2009; Meijer, Itard & Sunikka-Blank, 2009). In a mature stock, new construction has, thus, an almost negligible possibility to address contemporary challenges, such as reducing the overall energy consumption of the stock or solving changing spatial needs and preferences in housing and business. Furthermore, modern and post-modern theories, still dominating the education of architects and engineers, withhold underlying preferences towards the new, which is why they are unable to support practitioners with handling the historic complexity of the current and future built environment (Kohler & Hassler, 2002). Not to mention that in near future, many regions in Europe will not be growing but, on the contrary, shrinking (Giannakouris, 2010; Lanzieri, 2011). For these communities, practicing policies based on the old growth paradigm can have detrimental effects (see *e.g.* Rajaniemi, 2006). Therefore, the last 10–15 years have witnessed a growing interest in the research of the existing stock in Europe – a development that could be characterized as a paradigm change.

Other significant motivations for establishing the new line of research have been the notions of the impossibility and unsustainability of large-scale replacement in the building stock. First of all, authors have estimated that at the current pace of annual new construction, it would take several hundred years to replace the current stock (*e.g.* Meikle & Connaughton, 1994; Thomsen, 2007, as quoted in Thomsen & van der Flier, 2009). This suggests that research should find ways to extend the service lives of existing buildings significantly. Secondly, and even more importantly, authors have concluded that the replacement of existing buildings is, in fact, unsustainable, because it increases emissions in the short term being, therefore, harmful for climate change mitigation (*e.g.* Heinonen, Säynäjoki & Junnila, 2011) and, in the case of housing, tends to have adverse social effects (*e.g.* Mallach, 2011; Gilbert, 2011). The basis for the new paradigm was, in fact, postulated already half a century ago, when economist Kenneth E. Boulding (1966: 9–10) wrote his essay 'The economics of the coming Spaceship Earth':

> 'The closed economy of the future might ... be called the 'spaceman' economy, in which the earth has become a single spaceship, without unlimited reservoirs of anything, either for extraction or for pollution, and in which, therefore, man must find his place in a cyclical economical system. ... In the spaceman economy, what we are primarily concerned with is stock maintenance, and any technological change which results in the maintenance of a given total stock with a lessened throughput (that is, less production and consumption).'

The paradigm change coincides with a shift in larger cyclic phenomena of the global economy, titled Kondratieff waves after their inventor, economist Nikolai Kondratieff. These cycles are based on technological development and have been taken on by futures researchers, who are currently anticipating the transition to the 6th Kondratieff cycle. The new cycle will be characterized by a resource scarcity and a respective revolution in the efficiency of their use, leading to the decoupling of welfare generation and environmental degradation (Wilenius & Kurki, 2012: 86–96). Although the idea is still disputed, some researchers have even suggested that human influence on the planet has grown to such extents that it justifies declaring the beginning of a new geological epoch, the Anthropocene, and the end of the previous epoch, Holocene, that began as long as 12 000 years ago. The Anthropocene would be characterized by, besides climate warming and accelerated extinction of species, the global distribution and accumulation of 'technofossils', such as concrete, on the Earth's crust. (Waters et al., 2016). As if echoing Kenneth E. Boulding's words, futures researchers Wilenius and Kurki (2012: 95–6) write:

> 'The human economy must ... be restrained to function within the limits of the environment and its resources, and in such a way that it works with rather than against the grain of natural laws and processes. ... [A]ll changes in technical, economic, financial and institutional procedures should be subject to the need of decreasing overall resource consumption per unit of desired outcome, as well as the overall use of natural resources.'

Alarmingly with regard to these targets, policies have been deemed to favour demolition and new construction over life cycle extension (Hassler, 2009; Thomsen & van der Flier, 2011). With a more than 50% proportion of all extracted raw materials (EC, 2011) and a 25–30% share of all waste (EC, 2016), construction is already amongst the most environmentally burdening fields of industry in the European Union (EU). Thus, in 2008 EU issued a Waste Framework Directive that specifies a hierarchy (Figure 1) for future waste policies (EU, 2008: 10). The hierarchy's first three levels conform to the needs of the new 'post-growth' economy. This denotes that in future, resources should not be primarily extracted from the geo-ecosphere but from the anthroposphere: in case of buildings, the existing stocks. Industrial by-products have been recycled for long now, but these secondary flows are decreasing due to the increased efficiency of industrial processes. Moreover, the aims are now to shift from material recycling to the reuse of ready-made products. Avoiding the replacement of buildings in the first place should be increased, meaning that buildings should take up new uses. Building stocks should, hence, be considered as reserves for present and upcoming needs (Kohler & Hassler, 2002), and the evaluation of their value should not base on their current performance but the potential they withhold (Thomsen & van der Flier, 2011). Because the current economic system exacerbates the use of short-sighted management strategies, policies should be aimed at preserving the physical and cultural capital embedded in the building stock across generations. There is a need to find new tools for this work, because the limits of traditional conservation strategies are rather obvious in the context of entire stocks. (Hassler, 2009).

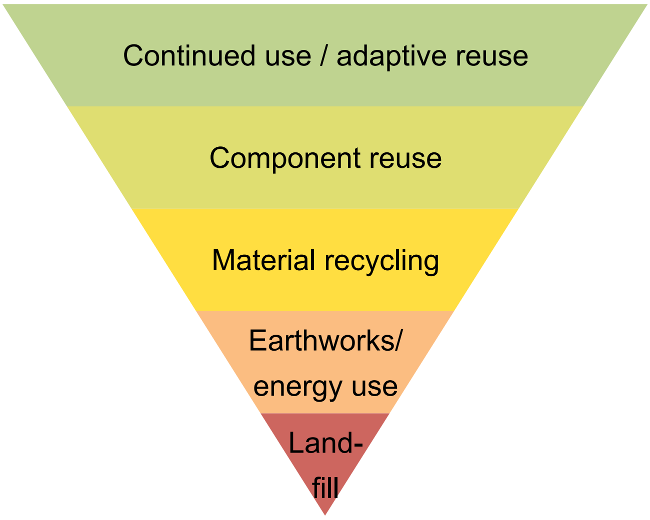


Figure 1. The waste hierarchy of the Waste Framework Directive (EU, 2008: 10), applied to the context of buildings and building stocks

Of course, research on the conservation or renovation of buildings has existed for long, in Finland and elsewhere in Europe. The difference that the new paradigm of building stock studies makes as a line of research is that the inquiry into the building stock is systematic and attempts to cover the dynamics of the entire stock (Kohler & Hassler, 2002). Effective policies can only be formulated and their implications measured against an adequate evidence base. In outlining the research agenda for building stock research, Kohler, Steadman and Hassler (2009: 450) establish that:

> 'The main societal objectives related to the building stock are to reduce its material and energy throughput, and maintain – on a sustainable basis – its capital and social value as a complex resource over the long-term'.

A seminal paper in establishing this line of research has been Niklaus Kohler and Uta Hassler's 2002 article 'The building stock as a research object' in the journal 'Building Research and Information'. In 2009, it was followed by a special issue in the same journal that outlined the scope of research further, with an editorial by Niklaus Kohler, Philip Steadman and Uta Hassler (2009) and papers by Hassler (2009), Meijer, Itard and Sunikka-Blank (2009) and Thomsen and van der Flier (2009), among others. The research is to target the in-use stock – its composition, properties, performance and adaptation potential – as well as the end-of-life phase of buildings, largely ignored so far (Figure 2). The latter topic was featured in a special issue of its own in 2011, with an editorial by André Thomsen, Frank Schultmann and Niklaus Kohler (2011), and, despite its quantitative and qualitative significance, is considered to be especially badly covered in research due to the difficulty of acquiring appropriate data. Thomsen, Schultmann and Kohler (2011) consider the omission as particularly problematic, because the aspects of buildings' mortality and survival are fundamentally intertwined, and the dynamics of the building stock cannot be understood without understanding both of them.

Thus, the special interests of this dissertation are directed at obsolescence and the end-of-life phase of buildings: at creating a knowledge base that increases understanding on the demolished and problematically vacant parts of the stock and on the reuse potential of quantitatively significant parts of the existing stock. Reuse refers here to continued use as buildings or dwellings (but perhaps in an adapted or modified form) as well as to reuse of components following their deconstruction. In accordance to the European waste policy and the paradigm underlying building stock research, this understanding can, at best, be used to help buildings to avoid coming to the end-of-life phase altogether, or to help formulate policy efforts targeting component reuse instead of low-quality recycling.

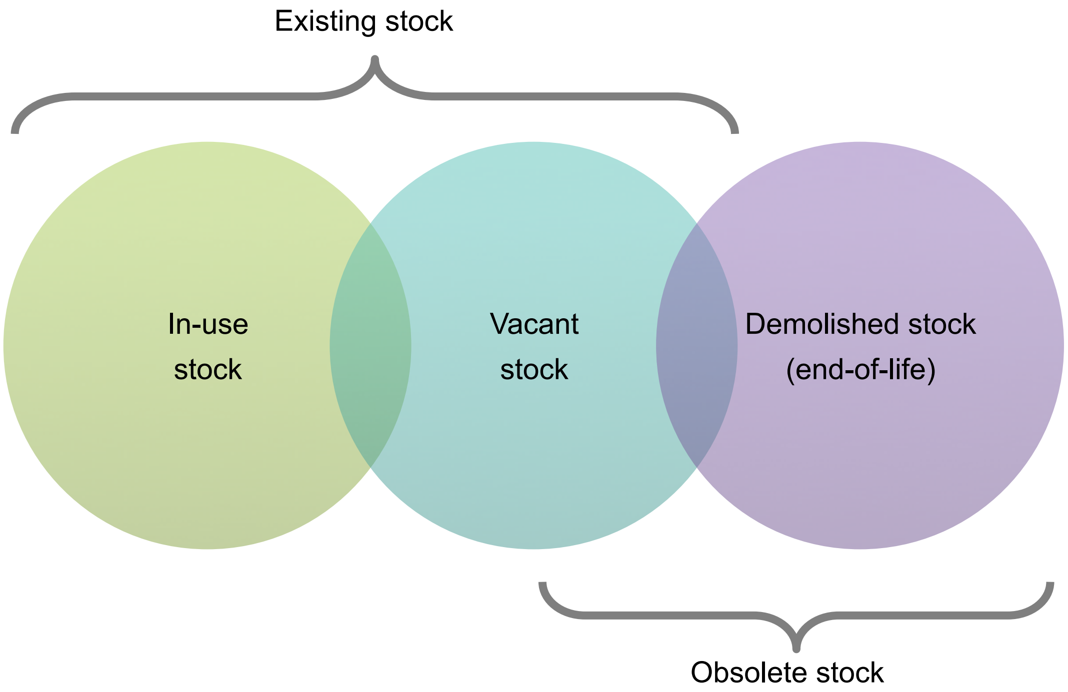


Figure 2. Conceptualization of the composition of the building stock and the relations between different parts thereof.

1.1 Background

Understanding how different parts of the existing stock perform (*e.g.* in terms of energy or housing needs) is a self-evident prerequisite for practicing policies on the sustainable management of the building stock (Kohler, Steadman & Hassler, 2009). Even though the importance of the topic is generally acknowledged (Kohler & Hassler, 2002; Kohler, Steadman & Hassler, 2009), there are very few studies that have been able to act as paragons for the papers that comprise this dissertation. The knowledge gap is wide and its systematic exploration is still in the very beginning. This is perhaps especially true for Finland, whose building stock is young in comparison to the stocks of many European countries. On one hand, the youngness of the stock denotes that the paradigm change is perhaps delayed in comparison to European countries with more long-lived stocks. On the other hand, it also means that the Finnish building stock is relatively well documented, which can make it easier to study than other stocks.

The knowledge gap can be outlined either thematically in the international context, as the global state-of-the-art, or in relation to the geographical location of the study, that is, Finland. To start with the former, the highest levels of EU's waste hierarchy (EU, 2008: 10), *i.e.* life cycle extension and component reuse, give the framework for the research. Thus, the topics chosen for the current study are underutilization and vacancy, demolition and deconstruction, potential for reuse as buildings and potential for reuse as components. The research on the first topic, *i.e.* vacancy, is well-established, but it is almost entirely concentrated on the housing market perspective. There is a basic understanding about the drivers, mechanisms and implications for the urban structure, but the phenomenon has not been considered from a stock-centred perspective. Although some of the vacant part of the stock can be considered to be in a transition phase between the in-use stock and demolished stock, vacancies are not included in any dynamic building stock models, at least as far as the current author knows. Secondly, demolitions, or exits from the building stock, are, then again, considered in the models, but the mechanisms they employ are based on theorizing because empirical evidence on the phenomenon is sparse. This is because little data has been available so far; the lack of data is especially evident on the non-residential part of the stock (Thomsen, Schultmann & Kohler, 2011).

Thirdly, the potential for life cycle extension (reuse as buildings) is perhaps the one topic that is covered the best in the state-of-the-art. There are both wide-ranging top-down studies as well as infinite numbers of case studies on specific aspects of renovation. It is typical of the research to take advantage of cohorts, *i.e.*, parts of the stock distinguished by types and ages of buildings. This study follows partially a similar approach, underlying which there is an assumption that these cohorts share certain focal properties that make their study meaningful. The challenge is, however, that the knowledge created this way is typically fragmented and sectorized, and rarely generalizable or useful from a stock-centred perspective (Kohler, Steadman & Hassler, 2009). It also tends to be obsessed with technical obsolescence, in particular energy performance, and to neglect use-related aspects. Fourthly and lastly, the state-of-the-art in the topic of component reuse is also, and quite understandably, dominated by technical approaches. Although the phenomenon is rooted in vernacular construction and thus touched upon in historical research, it has surfaced slowly in the research of contemporary buildings. On the level of entire building stocks, the perspective remains unaddressed. This is perhaps explained by the fact that it has only been during the last decade that resource efficiency has truly started to emerge as a major issue in Europe.

As the international research on these topics, seen from the building stock perspective, is only beginning, the state-of-the-art is even sparser in Finland. Vacant housing has been addressed briefly and incidentally from the national economy point of view in the beginning of the 2000s in two papers. These were the only studies that the current author was able to locate, which denotes that the issue is virtually unaddressed. The same applies to the demolished part of the stock, of which no studies have been conducted in Finland apart for the author's own work, as far as the author knows. The viewpoints are limited to heritage conservation, demolition technology and construction and demolition (C&D) waste assessment and treatment. This is rather understandable, because these phenomena tend to bear connotations of shrinkage, easy to ignore as irrelevant in a growth-oriented society. As in the international context, topics related to the assessment of potential for life cycle extension are covered best in Finland as well, but the research lacks the umbrella of the stock-centred paradigm. It is also dominated by technical aspects and focused on residential multi-family buildings at the expense of other viewpoints and building types. As for reuse of components, the situation is similar to the demolished part of the stock: there is very little existing research, much of which the current author has either authored or been involved in otherwise. Rather, the investigations have vested on C&D waste and material recycling. Thus, the knowledge gaps are wide, both in the international context and in the Finnish one.

1.2 Objectives and scope of the study

This dissertation research has an explorative nature. The purpose of the study is to probe the approaches for investigating the different potentials of the building stock and to explore what kind of results can be acquired using those techniques. The articles making up this dissertation share the research interest into the properties of the building stock, motivated by their possibility to act as reserves of buildings/housing or parts/materials. This is, in brief, the common thread of the entire dissertation, which combines top-down (Articles I and II) and bottom-up approaches (articles III and IV). The articles are, at heart, descriptive basic research on the Finnish building stock that participates in forming the basis for future applied research. The articles look at the building stock from perspectives that have until now been neglected in research. However, Articles I and II also consider the dynamics of building stocks on a very basic level. Understanding these dynamics may help to construct models that can predict changes in the building stock based on, for instance, demographic developments. The approach is, however, at this stage more descriptive than explanatory.

The research acts on two levels of scale: the first level (Articles I and II) is relatively general as it examines entire parts of the building or housing stock (the demolished part and the vacant part). The second level (Articles III and IV) zooms to a selected age-use cohort that acts as an example of a more detailed investigation of one distinctive part of the building stock that is yet wide-ranging enough to be generalizable. All the articles are independent in the sense they do not underlie each other. They have, however, been informed by the others following, naturally, the chronological order of their writing. The articles answer to the following research questions:

1. How are the reserves of obsolete (demolished, vacant) buildings like in Finland, *i.e.* where are they located and what is their composition in terms of building types, ages and materials? (Articles I and II)

2. Do these reserves exhibit connections with each other, new construction or the entire stock that could help to predict the formation of future reserves? (Articles I and II)

3. Is it possible to inventory the components of an age-use cohort in in order to create a basis for the evaluation of its reusability potential as components? (Article III)

4. Is it possible to describe the plan composition of an age-use cohort in typological terms in order to create a basis for the evaluation of its usability and adaptation potential? (Article IV)

Given the extent of the building stock, it is not possible to study all age-use cohorts at the same level of detail in one dissertation. Therefore, an exemplary age-use cohort was selected to illustrate the methods and outcomes of a more detailed investigation. The selection of this cohort, blocks of flats from the 1960s to 1980s, was influenced by 1) the significant research interest invested in this part of the stock in Finland and elsewhere in Europe, relating to its (energy) refurbishment needs (Kohler, Steadman and Hassler, 2009); 2) its large quantitative significance (Lahdensivu, 2012, see also Figure 4); 3) the fact that demolition in this cohort is exacerbated in Central Europe (Thomsen & van der Flier, 2011), and seems to be increasing in Finland, too; 4) its assumed repetitive character, and; 5) the availability and accessibility of a data source. The level of knowledge on this part of the stock is most advanced and relatively high in Finland, especially after the viewpoints of the current study are added to the present state-of-the-art.

1.3 Research approach, materials and methods

As this research situates within building stock studies, a branch of investigation shared by architects and engineers, the very nature of the field orientates researchers to look at large entities. Therefore, the study relies on a quantitative methodology. As a result, the dissertation differs from what is conventionally understood with architectural research, such as historical-interpretative or social research. Quantitative methods are, nevertheless, no strangers to architects, but they are perhaps more typical to urban studies in which Geographical Information System (GIS) aided analyses are used. Any research approach is inevitably informed by the discipline of its author. Perhaps more than the choice of methodology, the discipline guides the formulation of research questions. Thus, combining an architect's perspective with engineers' methods has resulted in providing answers to new questions that are not endogenous to either of the disciplines but, rather, societally relevant. This matter is best illustrated by the fact that most of the raw data of this dissertation has been available to researchers for decades but has simply not been used in this way prior to the current dissertation.

Due to the explorative nature of the research, there was a need to create 1) an overview of selected parts of the building stock in Finland, and; 2) as generalizable knowledge as possible. Therefore, the dissertation relies on vast, nationwide quantitative datasets that were either pre-existing but unnoticed by researchers or that were collected during the research. This makes the research approach extensive, which means that the objective of the research is to cover a large number of cases (Heikkilä, 2004: 16). The research is primarily descriptive, which is the basic form of quantitative research. This kind of research can answer questions like' what, who, what kind of, where and when'. (Heikkilä, 2004: 14). Parts of the research have also characteristics of causal research, interested in cause-effect relations and questions like 'why' and 'how' (Heikkilä, 2004: 15).

Two of the quantitative datasets have been extracted from the Building and Dwelling Register (BDR), which is a part of the Population Information System (PIS). The first of them encompasses records of all buildings demolished in Finland 2000–12, 50 818 in total (Article I). The other includes records of all residential buildings in Finland with vacant homes in mid-2014, 275 486 buildings with 1 100 267 occupied and 378 802 unoccupied homes (Article II). In terms of time, the study is cross-sectional. The datasets represent, thus, the entire populations at a given time, but in a temporal sense, they can also be considered samples of larger populations, at least in the short run. This is to say that there is an underlying assumption that demolition and vacancy profiles would not change suddenly, which is why studying already demolished buildings could help to understand future demolition as well. Furthermore, if the phenomena follow identifiable dynamics, bound to demographic changes, for instance, the changes to demolition profile could be predicted.

The latter two datasets capitalize on photographs of archival drawings of Finnish blocks of flats from 51 cities in different parts of the country. Article III uses plan, facade and section drawings of 276 of the aforementioned buildings, resulting in a dataset comprising of the dimensions and types of 39 795 concrete panels (26 287 wall panels and 13 508 hollow-core slabs). Article IV utilizes plan drawings from 320 buildings with 8745 flats in total.

The methods used are as follows. Articles I and II use GIS for structuring and processing the data. GIS has been proposed as appropriate in stock-centred research by Kohler, Steadman and Hassler (2009). The analyses of Articles I and II, as well as the entire Article III, rely on descriptive statistics. Descriptive approaches are not only typical to quantitative studies (Heikkilä, 2004: 14) but also to traditional architectural (historical) research (Kohler, Steadman & Hassler, 2009). These articles, however, differ from the latter by describing the composition of large parts of the stocks rather in numbers than in drawings. Article IV, on the other hand, is a relatively conventional typological study at heart. The differences to traditional typological studies lie at the target of the study (an entire cohort, dating to the contemporary time), the vastness of the data set and the computer-aided application of the graph theory in the creation of the types. The materials and methods have been described in more detail in the articles themselves, included in the end of this dissertation.

1.4 Research process and dissertation structure

The research the dissertation is based on was performed in two research projects at the School of Architecture in TUT. Articles I, II and III were written in project ReUSE, short for Repetitive Utilization of Structural Elements. This project was implemented in 2013–14 by the School of Architecture and the Department of Civil Engineering at TUT and VTT Technical Research Centre of Finland, which also acted as the coordinator of the project. TUT's part was financially supported by the Ministry of the Environment and Ekokem Corporation. Article IV was written in project MuutosMallit [Modification Models], short for Lähiökerrostalojen ja -asuntojen Muutossuunnittelun Mallit [Modification Models for Mass Housing Blocks and Flats]. The project was implemented in 2013–15 and funded by the Housing Finance and Development Centre of Finland (ARA). It was part of ARA's Asuinalueiden Kehittämisohjelma [Development programme for residential areas].

Chronologically, Article I was written first, and it was followed by Articles III, IV and II. Thus, the method and contents of Article II was informed by the experience gained in Article I, and the results of Article III informed the expectations for prospective findings in Article IV. Although the articles deal with independent topics, with regard to the entire building stock the knowledge construction proceeded in a hermeneutic circle.

The structure of the dissertation is as follows. Chapter 2 explores the theoretical foundation of the dissertation. The chapter starts off by describing the paradigm of building stock research, after which the topic is approached thematically. Chapter 3 describes the main results of the articles that make up this dissertation. The delivery of the results follows a thematic categorization, in which some of the topics of the articles have been combined. Chapter 4 discusses the implications of the study for research and practice (policies). The limitations of the study are also reflected on. Chapter 5 summarizes the contribution of the dissertation and suggests potential future research topics. The Author Accepted Manuscripts of the articles are placed in the end of the dissertation, after the reference list and the appendixes.

2 Theoretical foundation

2.1 Building stock research

Kohler and Hassler (2002) argue that building stocks have not been analyzed systematically in the past, but because the amount of renovation activities has already surpassed or will soon surpass that of new construction, a paradigm shift is now inevitable. The remark is applicable to Finland as well: as seen in Figure 3, the Finnish renovation market was slightly larger than the new construction market in 2014 (Rakennusteollisuus, 2015a). Unlike in new construction, in renovation the market is larger amongst residential buildings (RB) than non-residential buildings (NRB).

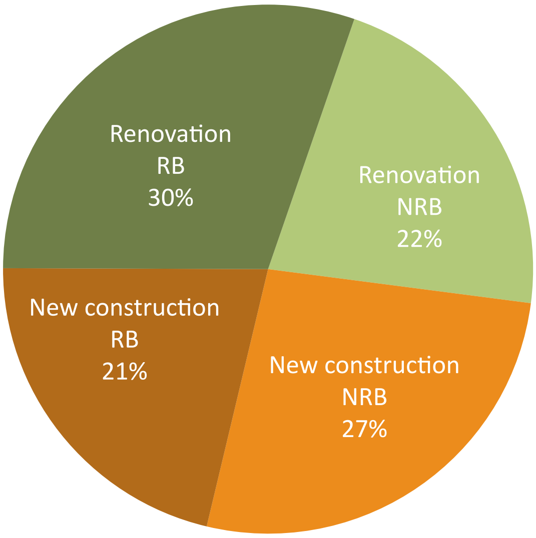


Figure 3. Distribution of value of Finnish building construction in 2014 (adapted from Rakennusteollisuus, 2015a). RB=residential buildings, NRB=non-residential buildings.

Kohler and Hassler (2002) have observed that wide-ranging data is typically better available on housing stocks, while NRB have mostly been studied on a case-to-case basis, with the focus on buildings with the most heritage value. They have observed that studies into the building stock are typically sectoral, can be divided into three categories: 1) housing surveys; 2) predictions on (energy) refurbishment needs; and 3) conservation-motivated studies of certain heritage-listed buildings. The weakness of these approaches is that as they focus on isolated parts of the stock, the definition of their objectives is narrow. Consequently, the findings have little potential for being generalized or for being applicable to other situations. (Kohler & Hassler, 2002).

The newer approaches, then, are characterized by: 1) the focus on the entire building stock; 2) the use of several different methods; and 3) the motivation on (although not necessarily success in) relating results between studies. Covered topics are strongly motivated by sustainability issues and include energy and environmental impacts; material and mass flows; resource reserves and C&D waste; empty and underutilized buildings and sites; and depletion of inbuilt land; in addition to the more traditional topics. (Kohler & Hassler, 2002).

Although Kohler and Hassler (2002) state that research that produces partial pictures of the building stock prevents more complex analyses of the interdependencies in the stock, they seem to acknowledge that creating understanding on entire building stocks is inevitably a form of patchwork. Kohler, Steadman and Hassler (2009) have granted concessions for sectoral approaches, as they have titled some research achievements within single disciplines as 'considerable advances'. They acknowledge that the need to understand the dynamics of the built environment takes place at different levels, from that of a singular building to that of the whole stock. Nevertheless, they state that it is typical of the research problems of building stock research to intersect a whole range of disciplines, rather than stay within one or two. Furthermore, they suggest that 'modelling buildings in a "neutral" form -- can reduce the need for input data, ensure data coherence, and above all become "bridges" between different approaches', such as energy, lighting, indoor air and use. (Kohler, Steadman & Hassler, 2009: 450). The point of the new paradigm is in enlarging the perspective, and the major obstacle on this path is the lack of reliable statistical data. Consequently, sectoral studies usually represent bottom-up approaches. A stock-centred view should, instead, adopt a top-down attitude. (Kohler and Hassler, 2002).

2.2 Basic composition of the stock

The information about the basic composition of the building stock is a necessary prerequisite for any investigations into it. In many countries, there is a lack of reliable statistical data concerning standing buildings. For instance, in Germany, there has been a need to combine information from several sources to create the basic data for a study that concerned the building stock of only one small town (Bradley & Kohler, 2007). Even less is known about demolished or vacant parts of stocks (Thomsen, Schultmann & Kohler, 2011). In Finland, however, the BDR contains the basic parameters of the building stock in the granularity of singular buildings, including their coordinates, and modelling its basic composition is, therefore, not necessary. A simplification of the stock is presented in Figure 4; Appendix I lists the entire classification of buildings and Appendixes II and III elaborate on the attributes included in the BDR. Because the BDR is a part of the PIS, the information about residential vacancy is also linked to the data. Furthermore, once buildings are demolished, their records are not removed from the BDR but their state of usage is changed in the registry. This makes the Finnish building stock as an outstanding object of study. As the BDR was founded as late as in 1980, its weak point is the lack of historical longitudinal data, as well as the accuracy of the attributes with regard to older cohorts. Furthermore, linking information about enterprises with business premises was discontinued in 1991, which is why information about the occupancy or vacancy of NRB is no longer available.

Since there number of different building types and construction years is immense, and buildings of different ages and uses differ from each other remarkably in many respects (size, layout, structures, performance, just to name a few), research typically relies on breaking the stock up to age-use cohorts. The basis for forming meaningful cohorts inevitably varies between countries and depends on the specific developments in their demographics, economic structure, urban structure and construction techniques. Representative cohorts are perhaps best identified by looking at the societal drivers and the development of construction techniques. Focusing on housing, Kahri (1979: 42) and Neuvonen (2002: 10–1) have juxtaposed societal developments, technical advances, architectural styles and urban (quarter) structure in Finland (Figure 5). Furthermore, if the building stock withholds standardized parts, the formation of cohorts can be eased further. Existing literature suggests several age cohorts for the Finnish stock, depending on the viewpoints of the studies, as seen in Table 1.

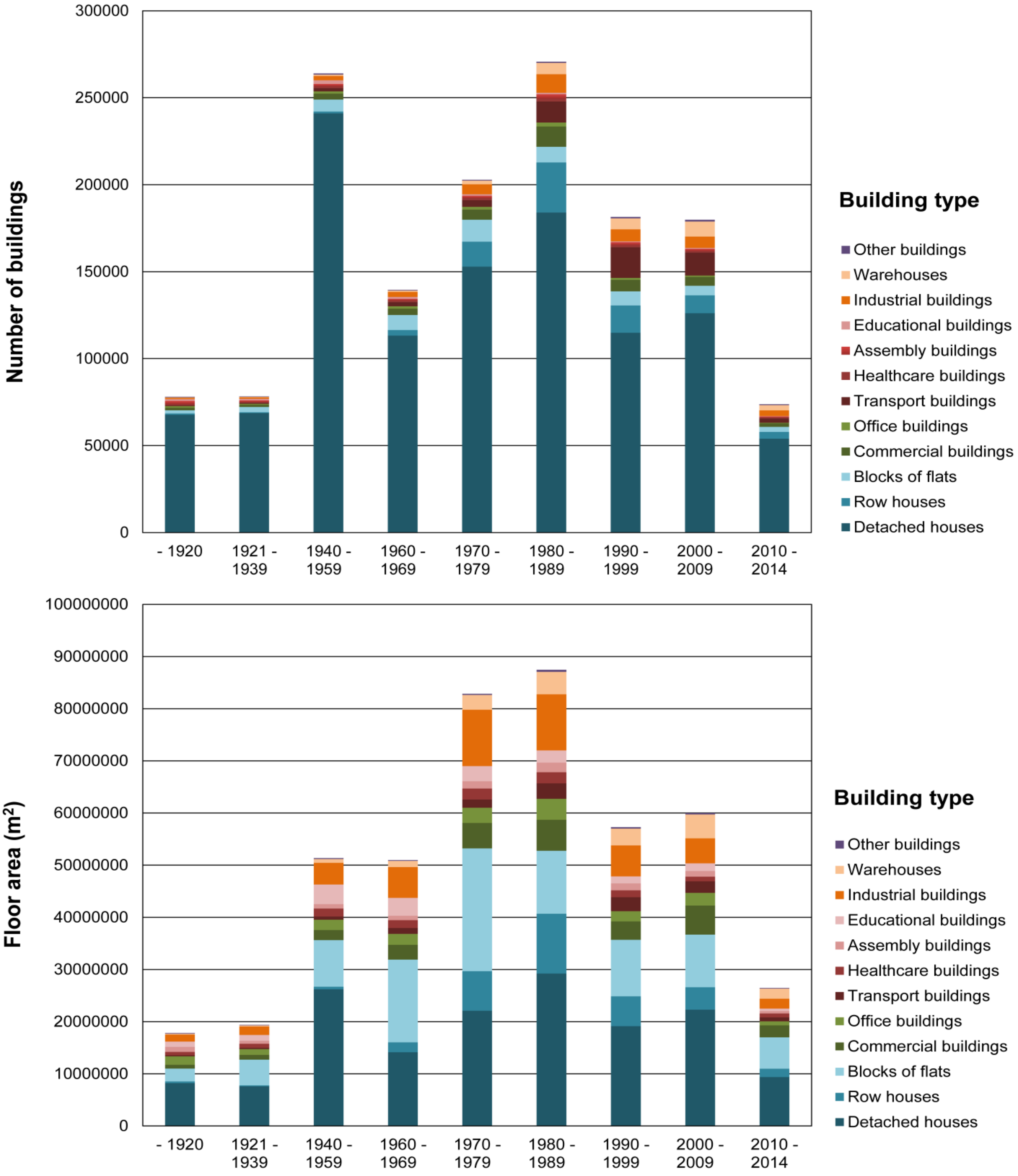


Figure 4. Basic composition of the Finnish building stock in 2014 (adapted from Statistics Finland, 2015). Note: The 1920s and 1930s are grouped together, and so are the 1940s and 1950s. The official statistics for the building stock omit free-time residential buildings, firefighting and rescue service buildings and agricultural buildings. Thus, the classification used in this dissertation is slightly different (see Appendix II).

The Finnish stock is notably young compared to most European countries (Hassler, 2009; Meijer, Itard & Sunikka-Blank, 2009). This is because Finland industrialized and urbanized relatively late; year 1957 is sometimes mentioned as a kind of watershed between more 'traditional' and modern construction (*e.g.* Siikanen, 2008: 17; Kammonen, 2012: 50). In all, 70% of all buildings and 80% of floor area have been erected after the 1950s (Statistics Finland, 2015). Figure 4 shows that the peak decades in terms of floor area are the 1970s and the 1980s, with around one-fifth of the stock built on each of these decades. This, however, also depends on the building type. For instance, the number of detached houses was increased in an unprecedented manner already during the post-war resettlement of evacuees from ceded areas. Blocks of flats, then again, started to increase significantly as late as in the 1960s.

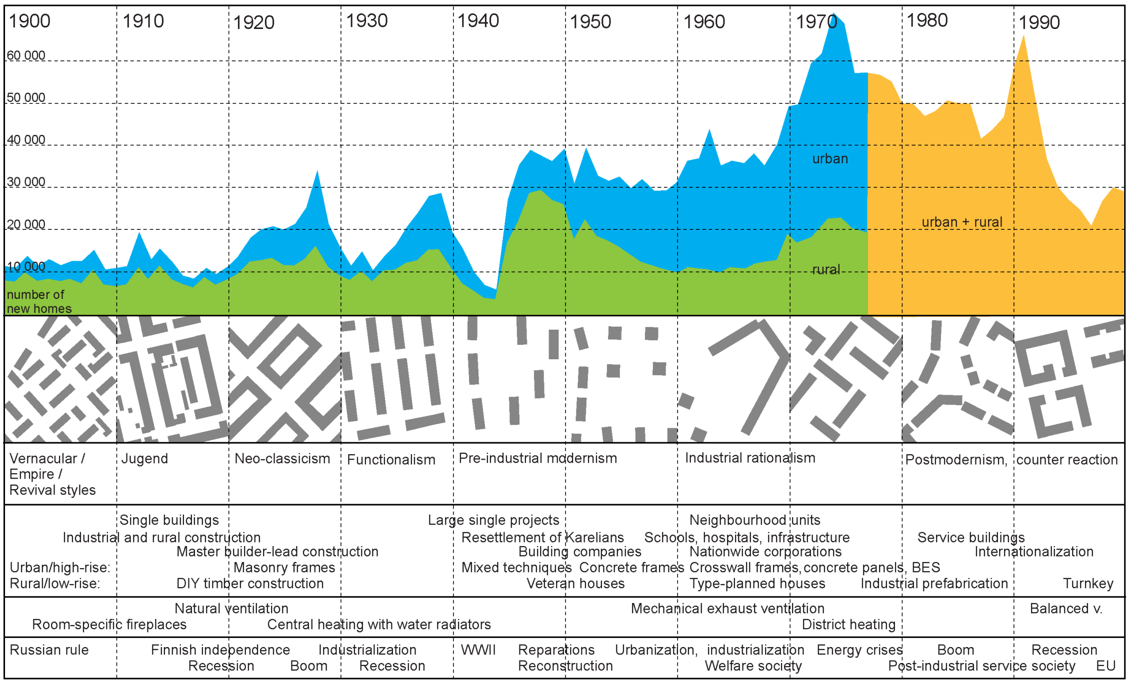


Figure 5. Conceptualization of the development of Finnish housing during the 21st century: annual new construction in urban and rural settings; urban (quarter) structure; architectural styles; project characteristics; technical solutions and societal developments juxtaposed with each other. (Adapted from Kahri, 1979: 42; supplemented with information from Hytönen & Seppänen, 2009: 301; Kakko, 2011: 120–1 and Neuvonen, 2002: 10–1). Note: Classifying communities into urban and rural has ceased due to many small municipalities adopting the title of a 'city' during the 1970s (personal communication, K. Degerstedt / Statistics Finland, 5.4.2016).

Viewpoint	Years	Characterization	Source(s)
Long-term geological processes	10^4 BCE–1950	Holocene, 'warming after ice age'	Waters et al., 2016
	1950–	Anthropocene, 'human influence'	
Global economic development	1780–1830	1st Kondratieff, 'steam engines'	Wilenius & Kurki, 2010
	1830–1880	2nd Kondratieff, 'railway, steel'	
	1880–1930	3rd Kondratieff, 'electricity'	
	1930–1970	4th Kondratieff, 'petrochemicals'	
	1970–2010	5th Kondratieff, 'ICT'	
	2010–	6th Kondratieff, 'bio age'	
Regional development	1880–1945	Early industrialization	Aro, 2007
	1945–1975	Centralization	
	1975–1992	Balancing development	
	1992–2005	Re-centralization	
Urban design	–1920/30	Closed quarters	Kahri, 1979
	1920–1940	Semi-open quarters	Neuvonen, 2002
	1940–1960	Open quarters	
	1960–1975	Windmill quarters	
	1975–1985	Irregular quarters	
	1990–	Nearly-closed quarters	
Architectural styles	–1910	Vernacular / historicism	Kahri, 1979
	1910–1920	Jugendstil	Standertskjöld, 2006
	1920–1930	Neoclassisism	Standertskjöld, 2008
	1930–1950	Functionalism	Standertskjöld, 2011
	1950–1960	Pre-industrial modernism	
	1960–1980	Industrial rationalism	
	1980–1990	Post-modernism	
	1990–	Contemporary era	
Blocks of flats	1880–1920	First emergence	Mäkiö et al., 1990
	1920–1940	Early development	Mäkiö et al., 1994
	1940–1960	Post-war period	Neuvonen et al., 2002
	1960–1975	Prefabrication	Neuvonen, 2006
	1975–	Increasing individualization	Neuvonen, 2015
Detached houses	–1940	Jugendstil / classisism	Kammonen, 2012
	1940–1959	Reconstruction	
	1960–1980	Standardization	
	1980–	Increasing individualization	

Table 1. Age cohorts used in literature. Greater geological eras and economic cycles are also given as a reference.

Some cohorts are already known better than others. As Kohler and Hassler (2002) suggest, the documentation of the housing sector is more advanced also in Finland. This is perhaps best explained by its large quantitative and qualitative significance. 85% of all Finnish buildings are residential, and they make up 63% of all floor area. In residential buildings, detached houses are the largest groups with shares of 89% and 55%, in a respective order. Only 5% of residential buildings are blocks of flats but 33% of residential floor area and 45% of homes are located in them. (Statistics Finland, 2015). They also make up the second voluminous building type category in the entire building stock in terms of floor area. The current research interests, professional renovation activities and state policies focus strongly on these multi-storey buildings. The reason is likely threefold: first of all, renovation processes of single-family houses are unproblematic due to the simple ownership structure, and their renovation is a fragmented market that attracts small enterprises only. Secondly, national housing policies are, above all, urban policies, which puts the emphasis on high-rise multi-family housing. Thirdly, the demographic changes in Finland show a further concentration tendency of population from the rural areas to community centres and cities. This trend is also related to the ageing of population, which is increasing the demand for multi-family housing (where maintenance is outsourced) and the requirements for its accessibility (the existence and retrofit of elevators, among other things). At the moment, renovation activities are greatest amongst buildings from the 1960s (Rakennusteollisuus, 2015b).

2.3 Structures and built form

The structure and material largely determined the basic nature of building plans, at least until the modern era disconnected the load-bearing structure from the spatial solution. Up to the first decades of the 20th century, Finland was largely rural, construction was mostly vernacular and massive horizontal log structures dominated the building stock. The Finnish timber construction technique was relatively modest in comparison to the Central European one, and the natural span of the tree trunk could rarely be superseded. As a result, the built form of most pre-20th century buildings (churches excluded) consisted of smaller and larger parallel log rooms whose dimensions were typically around 4–5 meters and around 8–10 meters at the maximum in one or one and a half floors. The plan types of historical houses are well documented from the simplest form of single log rooms to the more refined ‘Karolinian’ plan and its derivatives (Korhonen, n.d.).

In timber construction, the next development phase was the light-frame construction, but the fact that the logs were now sawn into studs and beams did not change the limits of their spans. The construction method became prevailing as a result of post-WWII resettlement and reconstruction, which was implemented with the help of type-planned 'veteran houses'. This type of housing factually encompassed large numbers of designs that differed from each other only slightly; they typically had a fourfold square plan and one and a half floors (Kammonen, 2012: 39–45). Wooden two-floor blocks of flats were also typical to the post-war era (Neuvonen, 2002: 85; Standerstskjöld, 2008: 81), but the literature virtually ignores them, perhaps because they were and still continue to be considered as temporary. Although the veteran house type fell out of use by the 1960s, Finnish detached housing has been characterized by type planning and prefabrication ever since. Ruotsalainen (2011) and Kammonen (2012) offer a cross-section to the historical development of such housing. In addition to providing historical overviews, the former focuses on the type-planned housing of the 1960s and the 1970s while the latter examines contemporary prefabricated houses. Although Ruotsalainen (2011: 60–5) briefly applies typological methodology, neither of the studies is systematic enough to provide generalizable knowledge about the plans of their targeted cohort.

Multi-storey construction emerged in the end of the 19th century. A vast in-depth research project into blocks of flats from all times was conducted during the 1990s and 2000s (Mäkiö et al., 1990; 1994; Neuvonen, Mäkiö & Malinen, 2002; Neuvonen, 2006; 2015), but it focused on structural options, materials and heating, ventilation, air conditioning (HVAC) systems and largely ignored the plan design. At first, walls of blocks of flats were made of load-bearing masonry. Their horizontal load-bearing structures consisted, however, of timber beams, which delimited the horizontal dimensions of the rooms to the natural length of the tree trunk. Thus, the plans of early blocks of flats are also formed by sequences of rooms in two or three rows. Although steel I-beams were also taken used in 1910s and reinforced concrete upstand beams prevailed from the 1920s to the 1950s, the principles of the plan formation remained unchanged. Brick walls and concrete upstand beams were replaced in the course of the 1950s and 1960s, first by in-situ cast concrete walls and slabs and eventually by prefabricated concrete panels. As the maximum span of both in-situ cast slabs and prefabricated massive slabs was 5–6 meters, their introduction had little impact on plan design. Post-beam or post-slab construction, which would have freed the plans from the limitations of the load-bearing walls, did not become common in Finland. Instead, the introduction of the pre-tensioned prefabricated hollow-core slab in the beginning of the 1970s offered this opportunity. (Neuvonen, 2002). Unlike the more historical construction, plans of multi-storey buildings have not been systematically investigated in the past. Mäkiö et al. (1990; 1994) do present a selection of plans for blocks of flats from 1940 to 1975, while Neuvonen, Mäkiö and Malinen (2002) and Neuvonen (2006; 2015) only include a handful of exemplary plans for buildings that are older or younger than that. None of the aforementioned, however, takes any stance on the prevalence of the plans within the cohorts.

Also Nippala (1988) presents a selection of buildings from different decades – in addition to blocks of flats, detached houses and row houses – that he deems 'typical' for their era. Besides containing information about structure types, the material includes plan, section and facade drawings, which appear to originate from specific buildings rather than being a result of fusing the properties of several buildings. Despite the fact that they have been adopted as the basis for instructions related to buildings' energy certification (Ympäristöministeriö, 2013), their true value for generalization is limited.

As for other building types, the knowledge is fragmented and extremely sparse. To the author's knowledge, no research has been conducted on other parts of the stock, case studies excluded. Due to the constraints set by construction techniques, it can be assumed that multi-storey RB and NRB (such as office buildings, schools and health care buildings) were likely similar in terms of plan design for long. The stylistic features of their architecture have also been classified in detail. Yet, both the aforementioned approaches offer little insight into their functional adaptability. The understanding that can be gained by looking at past design norms and guidance is also very limited. Nationwide norms on structural design have existed since the 1920s for concrete structures and since the 1940s for timber structures (Finlex, 2016), although the National Building Code of Finland was first issued as late as the late 1970s (Rakennustieto, 2015). This kind of norms, specifying mainly the maximum stresses, reveal little about structural systems and structure types. In addition to the official regulation, however, associations representing engineers (such as the Finnish Association of Civil Engineers, RIL) or manufacturers published additional instructional documents that promoted a variety of alternative structural solutions. The prevalence order of the different options, however, remains unknown. Later renovation-motivated research has had the tendency to concentrate on facades and HVAC, since these are the main objects in need of technical repair. Lahdensivu et al. (2015), however, list structural systems and component types for prefabricated concrete buildings of different functions but, as said, without the knowledge of their order of prevalence or their more specific properties.

Due to the aforementioned decoupling of the structure and plan design, structural norms are, alas, not very helpful with regard to spatial qualities of buildings, which is crucial with regard to their potential for continued use and adaptive reuse. The publication of architectural design guidance began in Finland in the 1940s. These documents, titled 'Building information (RT) files', were published by the Finnish Association of Architects (SAFA) until the 1970s, when their publication was transferred to a non-profit organization called the Building Information Foundation. Even though the RT files encompass today a wide-range of instructions from plans and details to structures and processes, their focus vested on RB for long. A natural explanation is that architects were likely less involved in the design of NRB. As the activities in commercial and industrial buildings often required long spans, structural engineering dominated their design. Table 2 lists the years when instructions on specific types of buildings were introduced in the RT files. The guidance typically focuses on very specific aspects of a plan, such as dimensioning rooms with given functions, but not on the combinations of these rooms into buildings. Therefore, the RT files are not very useful, either, from a stock-centred perspective.

Building type	Year introduced
Storage buildings	1948
Agricultural buildings	1973
Small industrial buildings	1982
Industrial buildings	1993
Warehouses	1993
Sheltered homes	1994
Offices	2000
Public buildings	2003
Schools	2008

Table 2. Chronological introduction of NRB in the RT files.(Rakennustieto, 2015).

In all, the state of research on the built form of the Finnish stock seems not to be extraordinary in international comparison. Typological methods have been used widely in historical research elsewhere, too, but much more sparingly in the investigation of the contemporary stock. Aside from the work of Philip Steadman, whose record includes several graph-theoretical studies on the typology of the British building stock since the 1980s and the relevant methodology (*e.g.* Steadman, 1983; Steadman, Brown & Rickaby, 1991; Steadman & Mitchell, 2010, just to name a few), there are only a handful of examples of such studies, such as Amole (2007), regarding Nigerian student housing; Ju, Lee and Jeon (2014, touching upon Malaysian blocks of flats, as well as Agyefi-Mensah et al. (2015), concerning Ghanaian public housing.

2.4 Dynamics and mortality

Once the understanding on the composition and properties of the stock is established on an adequate level, the interest shifts to its dynamics, *i.e.*, patterns of change within it and the drivers behind them. Kohler, Steadman and Hassler (2009: 451) state that:

> 'The sustainable management of the built environment requires the preservation of both natural capital and man-made resources, which means using artefacts for as long as possible'.

This puts special emphasis on the possibility to avoid replacing existing buildings with new ones (Kohler, Steadman & Hassler, 2009). Therefore, the drivers related to the demolition and life cycle extension (including refurbishment, renovation, extension and adaptive reuse) of buildings are of special interest for research concerned with building stock dynamics (Thomsen, Schultmann & Kohler, 2011).

Buildings' arrival to their end-of-life phase is integrally related to their obsolescence, which represents a serious threat to their existence (Thomsen & van der Flier, 2011). Thomsen and van der Flier (2011) present a conceptualization of obsolescence (Figure 5) that makes a difference between endogenous and exogenous obsolescence as well as physical and behavioural obsolescence, developed further in Thomsen, van der Flier and Nieboer (2015). Although in engineering, buildings' service life design still focuses on the physical durability of materials, research on the survival of buildings has concluded that these matters are not decisive. Instead, behavioural aspects, that is, aspects related to the owners and/or users of the buildings, make the difference in preservation and demolition decisions. (Thomsen & van der Flier, 2011). The physical and behavioural aspects are, naturally, more or less intertwined (Thomsen, van der Flier & Nieboer, 2015). For instance, the definition of endogenous physical obsolescence (Figure 5: A) is not independent of exogenous physical obsolescence (B) and endogenous behavioural obsolescence (C). Moreover, there is an extent to physical condition, energy efficiency and functional quality up to which they can be objectively measured, but deciding when they are 'poor' or 'low' is a question of subjective valorization, informed by the expectations of the actors and the standards set by current regulation (Raftery, 1991, as quoted in Kaivonen, 1994: 18). Similarly, exogenous behavioural obsolescence (D) is affected by the other quadrants: a poor housing market position can result from low physical quality of the buildings (A) or the conditions surrounding them (B), informed by prospective tenants’ expectations. Due to this, Thomsen, van der Flier and Nieboer (2015) specify that the model does not take a stance on causality but on cause-effect relations.

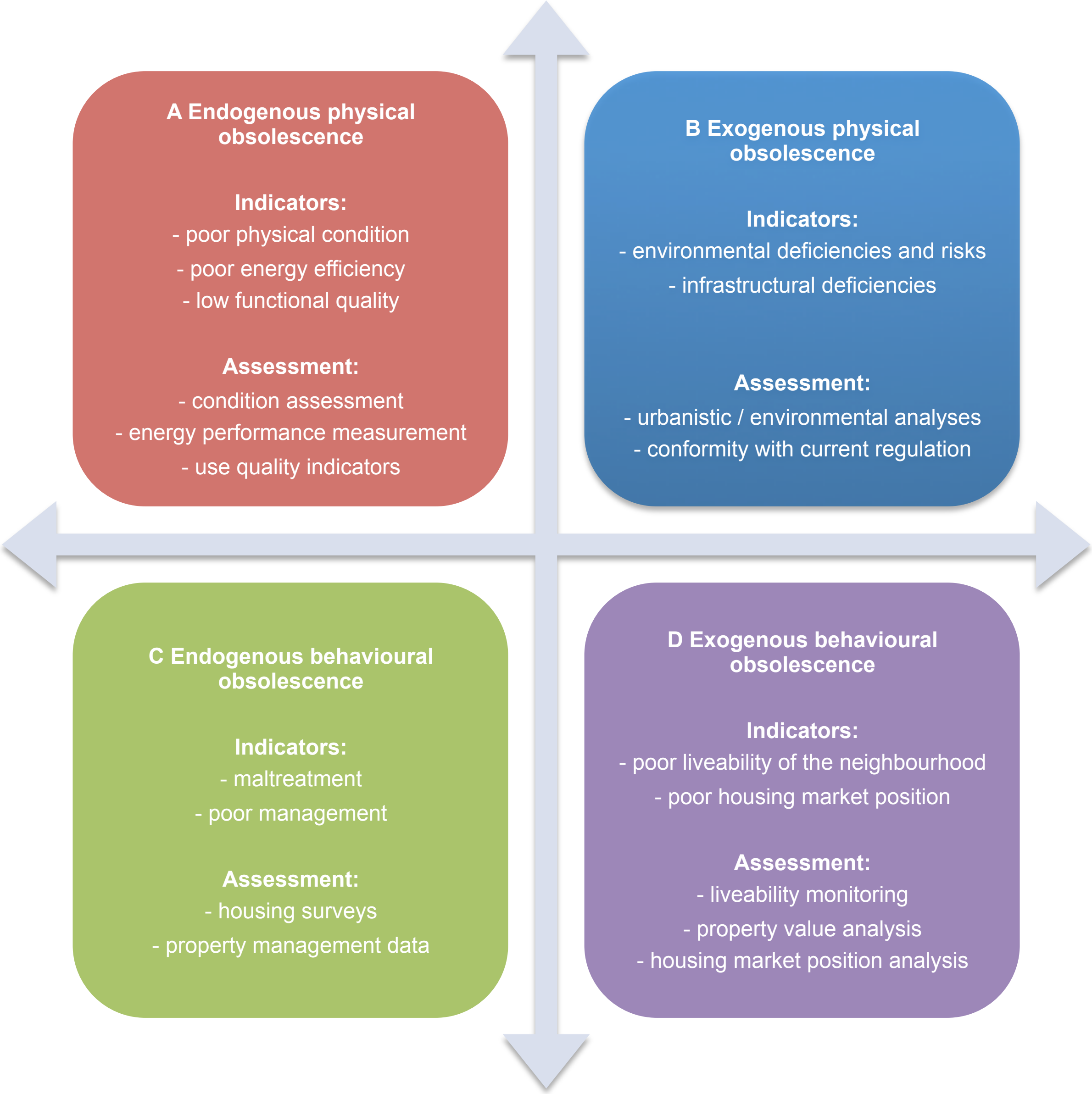


Figure 5. Conceptual model of obsolescence, based on physical/behavioural aspects and endogenousness/exogenousness of the emerging factors. (Adapted from Thomsen & van der Flier, 2011 and Thomsen, van der Flier & Nieboer, 2015).

The variety of demolition causes has, nevertheless, been discussed in Kohler and Hassler (2002) and Thomsen and van der Flier (2011). The determinative nature of the physical age has been rejected in both, and attention has been paid to 1) functional causes, related to changes in the activity the building was erected for (such as production or housing); 2) formal causes, related to their administration or tenure; 3) economic causes, related to land value or profit expectations, and; 4) social causes, related to segregation and urban decay. In long historical perspective, it has been said that ‘only what later eras can appropriate has a chance of survival’ across generations (Esch, 2011: 15). According to Törnqvist (1974, as quoted in Heikkilä, Niskala & Tuppurainen, 1982: 52), buildings’ endogenous potential for adaptive reuse is made out of adaptivity (acceptability to new use without changes) and modifiability (acceptability with changes). Whereas generously dimensioned and clearly organized spaces tend to be adaptable as such, modifiability is affected by architectural and structural qualities, such as the spatial solution and the structural system (Heikkilä, Niskala & Tuppurainen, 1982: 52). Thus, it seems unsurprising that RB have been stated to live longer than NRB due to the long-lived nature of the dwelling function (Bradley & Kohler, 2007; Thomsen and van der Flier, 2009; 2011) and that functionally flexible large buildings are believed to survive better than small buildings with a single given use (Schwaiger, Kohler, Hassler & Kierdorf, 2002). In addition, older buildings live longer than younger ones (Bradley & Kohler, 2007; Hassler, 2009; Aksözen, Hassler & Kohler, 2016). Moreover, the building type and ownership structure have been deemed to influence demolition decisions significantly. The decision making process is more enabling in freestanding buildings and buildings with a single owner, in comparison to attached buildings and owner-occupied multi-family buildings. (Thomsen & van der Flier, 2009). Echoing the structure of their model, Thomsen, van der Flier and Nieboer (2015) divide the dimensions of causes into endogenous/exogenous and physical/behavioural, *i.e.* natural/human causes.

Be it that the physical condition is not decisive, it is bound to influence the decision-making, since the costs and perceived risks of life cycle extension and component reuse are connected to it. There is little knowledge beyond case studies on the actual physical condition of buildings. In Finland, Lahdensivu (2012) is the only study that has examined the real condition and durability properties of an entire cohort using a large data set. Neither are there tools available for the estimation of buildings’ remaining service life and the extension achievable with repair measures. The current service life models (*e.g.* BY 50, 2012, for Finnish concrete structures) are intended for new construction and withhold an assumption that buildings will be demolished at the end of the designed service life, typically 50, 75 or 100 years. The targeted service lives are not informed by actualized lifespans of buildings but rather represent ‘best guesses’ (Rincón, Pérez & Cabeza, 2013). Recently, Aksözen, Hassler and Kohler (2016) have, however, demonstrated how actualized service lives can be uncovered by reconstructing long-term data. Moreover, the current service life design models also make another unrealistic assumption according to which the service life would end when deterioration is only about to begin. To overcome this inconsistency, Köliö (2011;

2016), for instance, has investigated the estimation of concrete structures' service life during the deterioration phase, but this kind of new tools are not yet widely in use.

On the level of entire building stocks, research on demolition patterns was started by Michael E. Gleeson (1981). He introduced the idea of applying population mortality models (also known as survival analyses) to housing stocks. Work in his footsteps was continued in the 1990s by Ivan M. Johnstone (1993) and in the 2000s by Bradley and Kohler (2007). The theory contains three competing views: that the mortality of buildings is 1) static; 2) variable or; 3) dynamic. The static model suggests that the mortality of different use or age cohorts is the same; the variable model assumes that it varies between cohorts due to the influence of construction techniques, for instance; and the dynamic model that the mortality varies, not only between cohorts, but in time, as well. (Johnstone, 1993: 4–5). In Finland, Salokangas (1978) has conducted a study relying on static mortality and calculated survival functions for different buildings types based on simply extrapolating data from the 1960s and the 1970s. Also Nippala (1988: 16–7) has presented survival graphs but without being very specific about the method of their generation. Although the shortcomings of the static mortality model are rather evident – buildings, unlike people, do not have a biological maximum age – the life table method continues to be applied in research (*e.g.* in Rincón, Pérez & Cabeza, 2013). This is despite the first dynamic housing mortality model having been introduced for more than 20 years ago (Johnstone, 1993). More recently, Bradley and Kohler (2007) have extended the application of Johnstone's method to NRB.

Whereas the interest of mortality models vests specifically on the demolished part of the stock, demolitions are also part of models that focus on the dynamics of entire building stocks. The purpose of these models (*e.g.* Sartori, Bergsdal, Müller & Brattebø, 2008; Hu, Bergsdal, van der Voet, Huppes and Müller, 2010; Holck Sandberg, Sartori & Brattebø, 2014), which typically target the housing stock, is to predict the needs for new construction and/or renovation. In Finland, VTT has developed models for both purposes and applied them to the Finnish housing stock since the 1980s or the 1990s (see *e.g.* Lehtinen, Nippala, Jaakkonen & Nuuttila, 2005). This kind of models tend to assume that population growth, new construction and demolition are interdependent, although there has been little empirical evidence. Although these models can be segmented, the mechanisms such models employ for mortality are often simpler than those of actual dynamic mortality models. For instance, normal distribution is typically used for survival functions of dwellings. The current models have not been deemed as appropriate for modelling the dynamics of NRB (Sartori et al., 2008), which means that they cannot be applied to entire building stocks, either.

Most demolished buildings can be considered to have been obsolete in one way or another, but the same does not apply to vacant buildings. Demolition is not always preceded by vacancy, and not all vacant buildings can be considered obsolete. First of all, all vacant homes are likely not really empty but rather underutilized due to the multi-locational lifestyles of their owners. Although the volume of voluntary underutilization in the housing stock is hard to assess, multi-locality is believed to be increasing (Haukkala, 2011). Secondly, 'real' vacancy is divided into a 'normal' (transactional) part and a problematic (structural) part (Couch & Cocks, 2013). The problematically vacant part of a stock can be characterized as being in-between the in-use stock and demolished stock, at risk of turning into a demolished part in near future. Unlike that of demolished buildings, the potential embedded in their material substance could possibly still be salvaged. So far, however, the interest has dwelled almost solely on the economic implications of vacancy. Although housing market models include vacancies (Zabel, 2014) and there are also chain models for simulating the domino effect (see *e.g.* Magnusson Turner, 2008), they do not appear to be included in any dynamic building stock models. Moreover, the existing research focuses on residential parts of building stocks. This is despite the facts that the basic mechanism – the equilibrium of supply and demand – (Glaeser & Gyourko, 2005; Zabel, 2014) is assumedly the same for RB as well as NRB, and that vacancy theory acknowledges the dynamic nature of the building stock, that is, that the amount of 'natural' vacancy fluctuates in time and varies between submarkets (Couch & Cocks, 2013; Hagen & Hansen, 2010). The question of unused or underutilized non-residential spaces has, however, been touched upon in urban planning, whose metaphors include 'urban fallows', 'brownfields', 'terrain vague' and 'drosscapes' (Ylä-Anttila, 2010a;b). In Finland, methodology has been developed for computer-aided mapping of urban fallow areas, but due to the lack of registry data, identifying the state of usage requires fieldwork (Alppi, 2010).

2.5 Metabolism and resilience

A step forward from understanding the dynamics is modelling the entire metabolism of a building stock, covering inflows and outflows of materials, substances and energy from a life-cycle perspective. These models originate from ecology and system theory, and, applied in building stocks, enable quantifying their environmental impacts through life cycle assessment (LCA) or material flow analysis (MFA) (Kohler, Steadman & Hassler, 2009). The existing models typically target solely the housing stock (*e.g.*

Müller, 2006; Bergsdal, Brattebø, Bohne & Müller, 2007) and rely on the same basic mechanisms as the aforementioned dynamic building stock models. In addition, however, they couple the energy use and/or material content of buildings with the modelled dynamic behaviour of the stock. Such analyses require the existence of data regarding the energy performance and embedded materials of the stock. Alas, such data is very seldom available reliably, especially at the unit or even at the cohort level, which is why extreme simplifications are made (Meinander & Mroueh, 2012: 19). As a result, the outputs of the models are quite rough, typically describing mass flows of basic materials (such as wood), without any information about their refinement (*e.g.* sawn timber, particle board, glulam) or the products they come in (*e.g.* beams, columns, trusses).

This conforms to the current situation in which the metabolisms of building stocks are based on a cradle-to-grave circulation, where virgin materials are extracted from the geo-ecoshpere and disposed of at the end of their life cycle. In order to reduce the environmental impacts of construction to a sustainable level, however, there is a need to decouple the consumption of materials from the service provision of buildings (Pauliuk & Müller, 2014). Reducing the throughput can take place firstly by slowing down the entire metabolism and secondly by creating closed cradle-to-cradle loops within it. Decelerating the metabolism denotes avoiding replacing buildings with new ones, in other words, life cycle extension of the existing stock. The survival age of buildings is, indeed, a basic parameter in LCA and highly relevant to their environmental impacts. (Rincón, Pérez & Cabeza, 2013). The shorter the building's life, the greater is the share of impacts from its production (embedded or grey energy). Although it has been suggested that there is a need to extend the service lives of buildings up to several hundred years merely for practical reasons (Meikle & Connaughton, 1994; Thomsen, 2007, as quoted in Thomsen & van der Flier, 2009), buildings' real average lives can be unreasonably short and around only a couple of decades (*e.g.* Salokangas, 1978; Nakajima & Murakami, 2008). The transition to cradle-to-cradle loops requires activating the exploration and utilization of anthropogenic material stocks.

Metabolism is also an aspect of resilience, a concept lately adopted from ecology to urban studies. Resilience is a capacity of survival and recovery, or, in the context of cities, their capability to adapt to change. The 'ecosystems' of cities consist, among other things, of their building stocks. These stocks are slow to change, and they can, thus, be treated as a reserve (a buffer) that contributes to cities' resilience (the 'urban fallow' approach represents this view) or as a problem that deteriorates it. (Pickett, McGrath, Cadenasso, Felson, 2014). Urban areas are usually not even closely self-sufficient, neither in terms of construction materials for new buildings nor with regard to

C&D waste treatment of demolished buildings, but forced to rely on their hinterlands. Problems with the extraction and disposal of materials have already emerged in Central Europe where built and cultivated environments dominate over virgin nature (Sippola & Ratvio, 1994; Müller, 2006). Urban harvesting, *i.e.* extraction of materials from the anthroposphere, has been suggested to be an integral part of resilience (Agudelo-Vera, Leduc, Mels & Rijnaarts, 2012).

2.6 Theory synthesis

A new paradigm of building stock research has emerged for two reasons: firstly, because of the maturing of European building stocks and secondly, due to the growing importance of anthropogenic material reserves, as opposed to virgin resources. The difference to existing research approaches is the adoption of a top-down attitude towards the stock and its dynamics and the aim of producing generalizable knowledge from vast statistical data concerning the stock or parts thereof. The main objective underlying the new paradigm is sustainable long-term value preservation of the stock. Thus, building stock research has a normative dimension: it aims at creating the knowledge base for policy-making. Currently, developed human societies consume building materials at an unprecedented and, alas, an indisputably unsustainable pace. There is an urgent need to reduce this throughput, that is, to slow down the metabolisms of cities. From this follows a need to understand better the end-of-life phase of buildings as well as their potential for life cycle extension. This requires understanding on the buildings themselves (their spatial and structural qualities) as well as on the mechanisms of change (dynamics) of the building stock.

It is symptomatic of the current situation in Finland and elsewhere that research has so far 1) concentrated on RB and tended to neglect NRB; 2) relied on isolated case studies of architecturally significant buildings, or; 3) whenever a more stock-centred perspective was adopted, had a very narrow focus. Finland, however, unlike many other countries, has a good basic registry data about the consistency of its building stock and the change thereof since 1980, which is beneficial for the paradigm shift. Current Finnish research with an interest in existing buildings has, however, concentrated almost solely on technical repair needs in a specific age-use cohort, *i.e.* residential multi-storey buildings from dominating construction decades. Aspects related to the current and potential new uses of buildings have been largely ignored, although, in general, behavioural viewpoints are found to be more decisive for the survival of buildings than technical matters. From the stock-centred perspective, understanding on the spatial qualities of building cohorts comes off weak, as, apart for vernacular construction, no systematic inquiries exist.

Due to the lack of empirical data on demolition, understanding on the end-of-life phase of buildings is largely based on theorizing. The theory includes conceptualizations of obsolescence, static and dynamic mortality models, dynamic building stock models and metabolism (MFA) models. Most models tend to apply far-reaching simplifications and contain fundamental assumptions about the end-of-life phase of buildings that are yet to be verified with real data. This applies also to the material content of buildings needed for MFA, not to mention their component composition and data needed to assess the functional adaptability and modifiability of their spaces. Information on the latter two aspects is necessary for estimating resources available for higher-level reuse, as follows from the targets of EU's waste hierarchy. Harvesting resources from anthropogenic stocks will be integral to resilient future cities, where the service provision of physical spaces has been effectively decoupled from the throughput of materials. However, the theory is still relatively vague about the causes of demolition as well as the relation of obsolescence and demolition, although mitigating obsolescence is focal for preventing buildings from reaching their end-of-life phase. Moreover, existing models ignore the role of vacancies, although structural vacancies represent the shift from the in-use stock to the end-of-life.

To sum up, there is a need to enlarge the perspective regarding the research of existing buildings and bridge the gaps between different sectoral approaches. Due to past and current restricted viewpoints, the understanding on fundamental phenomena, such as obsolescence, demolition and vacancy, is very limited. Empirical research is crucial for verifying or challenging current theoretical assumptions. At the same time, there is also a need for such bottom-up research on material and component compositions of cohorts as well as their spatial and structural qualities that is able to produce generalizable results, combinable with other sectoral findings and top-down approaches to stocks, such as dynamic stock and metabolism models. All findings, empirical or theoretical, should contribute to supporting sustainable decision-making.

3 Research contribution

This dissertation enlarges the understanding on building stocks with the help of vast statistical data on Finnish buildings. Firstly, the research looks at demolition and vacancy from top-down perspective with data covering entire populations of demolished buildings and vacant RB at given points of time. The first two subchapters:

1) provide findings about the composition and location of the demolished part of the building stock and the vacant part of the housing stock that are to be understood as possible deposits of resources (Articles I and II, Chapter 3.1); and

2) discuss interdependencies and dynamics of the aforementioned parts of the stock with other parts thereof, such as the newly constructed part or the stock in its entirety, as well as the population and its dynamics (Articles I and II, Chapter 3.2).

Then, the perspective changes from top-down to bottom-up. Using an exemplary cohort (block of flats from the 1960s to the 1980s), the third subchapter:

3) suggests how to create the basis for the assessment of an age-use cohort's component composition and the respective potential for component reuse, as well as the assessment of a cohort's plan composition and the respective potential for continued use as buildings or dwellings (Articles III and IV, Chapter 3.3).

Lastly, the dissertation:

4) combines the top-down and bottom-up approaches by putting together results from the aforementioned sections of research (Articles I–IV, Chapter 3.4); and

5) summarizes the contribution of the work (Chapter 3.5).

3.1 Reserve made up by the obsolete stock

3.1.1 Overview

Between years 2000 and 2012, between 3251 and 4508 buildings were demolished in Finland annually, which points at dynamic mortality of Finnish buildings. In total, 50 818 buildings with more than 9 million m^2 of floor area perished during the period. On average, the annual demolition rate was 0.25%, but as corresponds with theory, there was a major difference between RB and NRB: the average demolition rate was 0.15% for the former and 0.65% for the latter. The number of demolished homes was 28 158, which equals to an annual average of 2166 homes. (Article I). The size of the vacant part of the stock is much greater, although only RB were covered in this part of the study. In mid-2014, the number of buildings with unoccupied homes was 275 486. In addition to the 378 802 vacant homes in them, they also encompassed 1 110 267 occupied homes; this made their gross vacancy rate 12.7%. 64% of the homes were long-term vacant, and in 68% of the buildings, the vacancy can be labelled problematic due to its duration and extent. Thus, the number of problematically vacant homes is more than hundredfold compared to the annual average number of demolition. There was over 35 million m^2 of floor area in this part of the vacant stock. 163 966 buildings or 13.0% of the stock of residential buildings were completely vacant; the floor area in this part of the stock was over 11 million m^2. (Article II).

There is an underlying assumption that the extent of vacancy in the non-residential part of the stock would be at least equal to that of the residential part. However, it can be speculated that the vacancy rate of NRB may be even greater, similarly as its demolition rate. Official statistics are not available, but Catella (2015) has published vacancy rate estimations for retail, office and industrial/warehouse spaces in the nine largest Finnish cities, and the capital region can be used as an example here. While the vacancy rate of housing is 6.7% there (raw data for Article II), the rate is nearly the same for industrial and warehouse buildings (6.6%) but as much as 13.4% for offices (Catella, 2015: 14), which is more than double the residential vacancy rate. One should, however, keep in mind that the share of NRB in the entire stock is 15% (in terms of floor area, 37%), *i.e.* clearly smaller than that of RB. Table 3 compares annual demolition and vacancy figures of selected RB and NRB building types.

Building type	Demolished (m^2)	Vacant (m^2)	Demolished /vacant (%)
Detached houses	30 675 [1]	1 381 558 [2]	2.2
Row houses	2 587 [1]	395 830 [2]	0.7
Blocks of flats	8 972 [1]	3 448 593 [2]	0.3
Offices	22 463 [1]	1 468 400 [3]	1.5
Commercial	20 174 [1]	355 500 [3]	5.7
Industrial / warehouses	111 648 [1]	846 100 [3]	13.2

Table 3. Relation of annual demolished and vacant floor area in selected building types (of which data was available) in the nine largest Finnish cities (Helsinki, Espoo, Vantaa, Tampere, Turku, Oulu, Jyväskylä, Lahti, Vaasa). Notes and sources: 1) annual average from 2000–12, raw data of Article I; 2) situation in mid-2014, raw data of Article II; 3) situation in mid-2015, Catella, 2015: 14.

3.1.2 Building types

Like in the entire building stock, detached houses are the most prevailing building type amongst both demolished buildings and buildings with problematic vacancies. This is because small buildings are emphasized if the composition of the stock is examined by the count of buildings. The picture is different if looked from the viewpoint of floor area. Amongst demolished buildings, the most notable groups are, then, industrial buildings (19%), detached houses (16%), public buildings (14%), commercial and office buildings (13%) and warehouses (12%). In all, NRB are emphasized with a 75% share of all demolished floor area, although by count, practically as many RB and NRB were demolished. (Article I). Although the examination of vacancies omits NRB, the order or building types is also turned: there is more floor area in blocks of flats with problematic vacancies than in detached houses, be it only slightly. (Article II). While the floor area of demolished blocks of flats is only 260 700 m^2 (Article I), that of problematically vacant apartment buildings is over 15 million m^2, while there are overall almost 94 million m^2 in this stock. Overall, the phenomenon, nevertheless, is more severe in the stock of detached houses. (Article II). Figures 6 presents the relations between the number of obsolete buildings and their floor area.

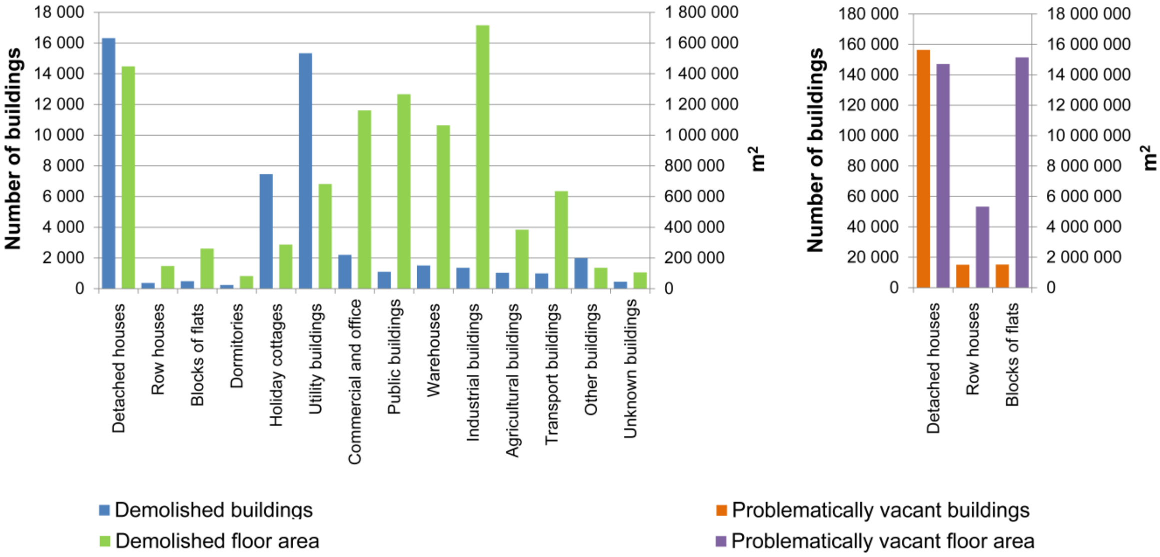


Figure 6. The numbers and floor area of obsolete buildings of different types: on the left, demolished buildings; on the right, residential buildings with problematic vacancies. (Article I; Article II). Note the different scales of the axes: the extent of vacancy is manifold in comparison to demolition.

3.1.3 Building ages / construction decades

At the time of demolition, NRB were on average younger than RB: the average age of demolished NRB was 43 years (standard deviation [s.d.] 24 years) and the average age of RB 58 years (s.d. also 24 years). The lifespan of buildings classified as 'others' was the shortest, just over 30 years (s.d. 13 years), while those of detached houses and blocks of flats were the longest, over 60 years (s.d. 24 and 20 years, in respective order). NRB types with highest average survival ages were utility buildings (47 years, s.d. 25 years) and public buildings (41 years, s.d. 25 years). These averages are not to be confused with the average survival ages of buildings, whose calculation would require information on buildings that have been demolished prior to or after the examination period and on buildings that still stand. (Article I, Raw data of Article I). Figure 7 presents the average ages of different building types even in more detail.

In all, buildings younger than 60 years old were accountable for 80% of demolished floor area. Most of the demolished floor area originates from between the 1950s and the 1980s, especially the 1960s and the 1970s. Detached houses dominate the demolition of floor area up to the 1950s. The amount of demolished industrial floor area

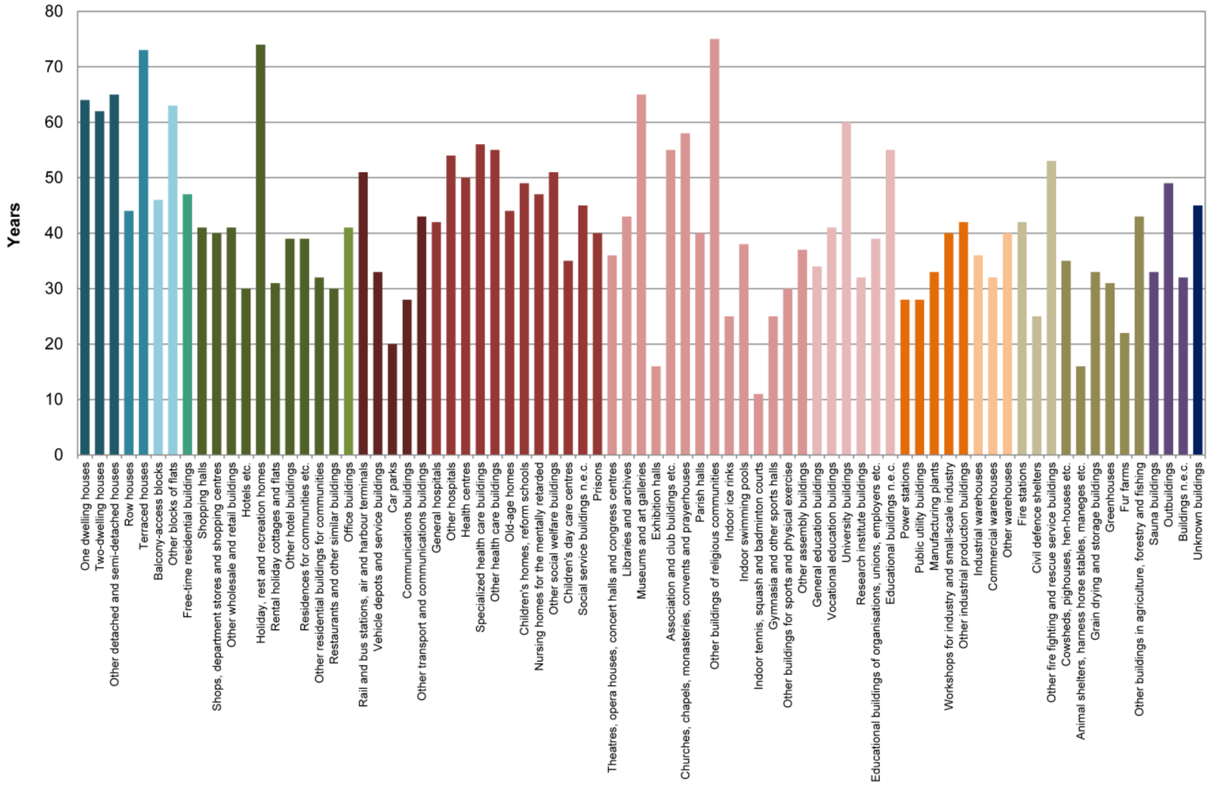


Figure 7. Average ages of demolished buildings in all building classification categories (Appendix I), 76 building types in total, plus buildings whose type is unknown. Note: Colour code follows that of Figure 4 with the exceptions that Figure 4 omits free-time residential buildings (turquoise), firefighting and rescue service buildings (grey), agricultural buildings (brown) and unknown buildings (navy). (Raw data of Article I).

becomes significant starting from the 1930s, and warehouse floor area from the 1970s onwards. Also public buildings, commercial and office buildings and utility buildings are represented in significant numbers in most decade cohorts. (Article I).

When it comes to RB with vacancies, the share of buildings with problematic vacancies is, as a rule, the higher the older the decade cohort is. However, the volume of the oldest cohorts is small in the big picture. In absolute numbers, the largest number of buildings with problematic vacancies occurs in the largest decade cohort, which varies according to the building type, being the 1940–50s for detached houses, the 1970s for blocks of flats and the 1980s for row houses. The relationship is, however, not linear with either the age or size of the stock. (Article II).

3.1.4 Construction materials

The construction material composition of demolished and problematically vacant buildings reflects that of the entire building or housing stock (Figure 8). Wood dominated as the construction material of demolished and problematically vacant detached houses and row houses, as well as that of demolished holiday cottages, utility buildings and agricultural buildings. Concrete prevails amongst demolished and problematically vacant blocks of flats, and amongst demolished commercial and office buildings, industrial buildings, warehouses and transport buildings. Demolished public buildings, then again, were made out of timber as often as they were made out of concrete. (Article I; Article II).

When the issue of construction material is approached through floor area, the results are similar in the order of magnitude irrespective of which part of the obsolete stock is looked at (the demolished part or the problematically vacant part of RB). Amongst demolished stock, the share of timber is 41% and the share of concrete 35%, and

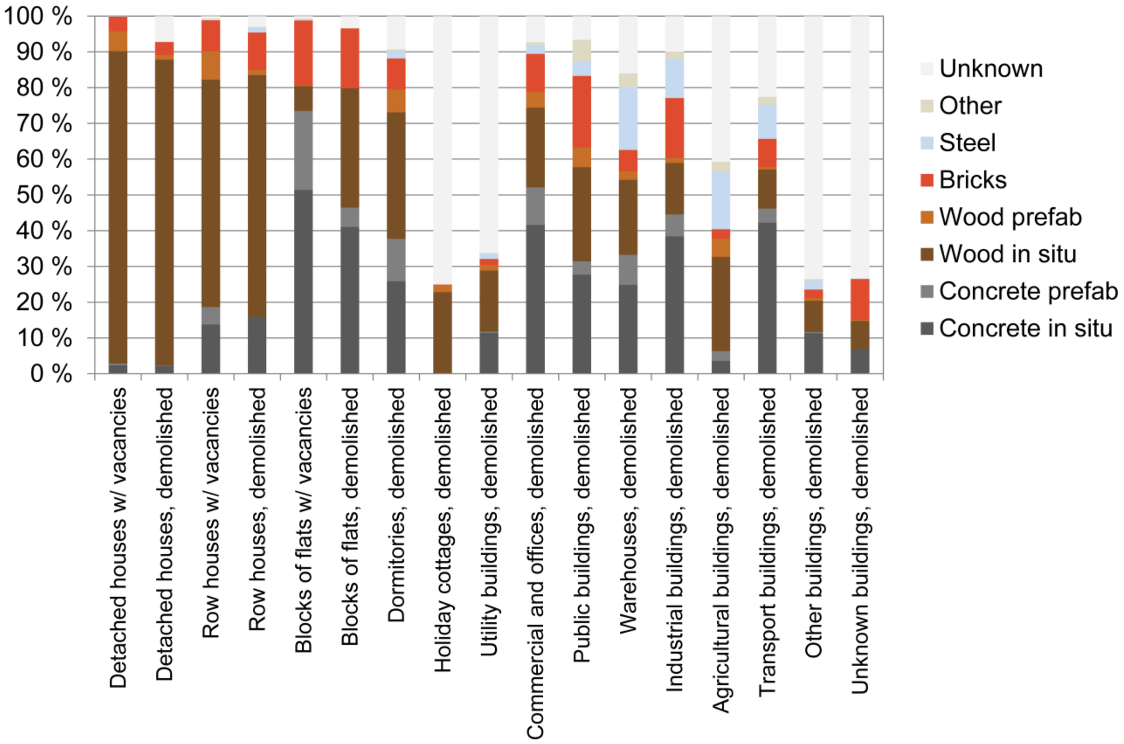


Figure 8. Construction materials and methods of demolished buildings and residential buildings with problematic vacancies. (Article I; raw data of Article I; Article II).

amongst the problematically vacant part, the figures are 52% and 36% in a respective order. Of the floor area in concrete buildings, 16% was prefabricated amongst demolished buildings and 29% amongst buildings with problematic vacancies. This is when the floor area the construction method of which is not recorded is interpreted as *in situ* cast. If this assumption is not made, the share of prefabrication amongst demolished concrete buildings rises to 50%. Moreover, many buildings are not completely but partially prefabricated: usually the horizontal structures are in situ cast and the vertical ones, especially facades, may be prefabricated (Neuvonen, 2006: 150). Unfortunately, it is not possible to distinguish these buildings from the data. In both parts of the stock, the share of bricks is around 10%, while the proportion of steel is 6% in the demolished part and negligible amongst buildings with problematic vacancies because it is commonly not used in RB. (Article I; Article II).

3.1.5 Geographical locations

When assessing the magnitude of reserves, the absolute numbers of demolished square meters are perhaps more decisive than values related to their relative frequency, which is looked into in Chapter 3.2.6. In these terms, the demolitions focus geographically on urban and growing municipalities, although they are in the minority amongst all municipalities. Moreover, the more urban the area type, the more demolition occurs (Figure 9). In the case of most building types, most floor area is demolished in inner cities. The degree of urbanization and the distribution of demolished floor area into residential and non-residential also coincide: the share of non-residential area is the greater the more urbanized the area and varies from 88% (inner cities) to 63% (sparsely populated countryside). (Article I).

In the rurality, detached houses, utility buildings and holiday cottages, *i.e.* minor buildings, make up 80–90% of all demolished buildings by count (which equals to 46–51% of demolished floor area). In inner cities, then again, nearly 70% of floor area originated from commercial and office buildings, industrial buildings, warehouses and public buildings (in a respective order), but they made up only 22% of the demolished buildings by count. Despite the prevalence of residential buildings in the countryside, in absolute numbers the majority of residential demolition occurs in urban contexts. Other residential buildings being in the minority, detached houses also make up a significant share of demolished buildings and floor area in cities. (Article I).

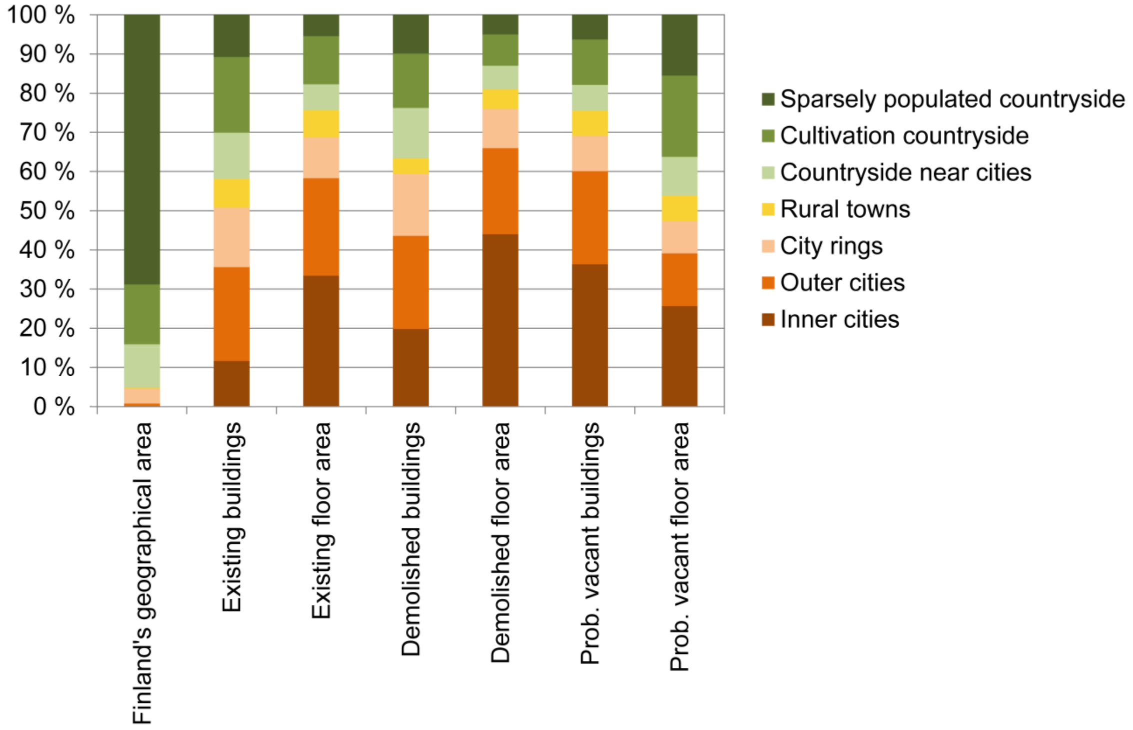


Figure 9. Distribution of Finland's geographical area, existing buildings, existing floor area, demolished buildings, demolished floor area, problematically vacant buildings and their floor area on different geographical area types. Sources: Article I; Article II; Suomen ympäristökeskus (2014) (data on existing buildings).

The majority of demolished homes, regardless of the building type, were located in growing communities, 61% in total. The share of demolished flats is highest in growing communities. In inner cities, every third demolished home was located in a block of flats. (Article I).

When it comes to buildings with problematic vacancies, the stocks of detached houses and row houses are spread around a vast geographical area of the countryside, whereas respective blocks of flats are geographically concentrated to cities and, in particular, their centres. When the buildings are examined by type and location, blocks of flats in cities contain the largest amount of floor area. They are almost equalled by rural detached houses, but there is a significant difference in the geographical concentration of the floor areas: the countryside covers 95% of Finland's area, while cities cover the remaining 5%. (Article II).

Remarkably, there tends to be more buildings with problematic vacancies than those with normal vacancies regardless of the area type. Only blocks of flats in all city sub-areas and row houses in outer cities make an exception. Yet, more than 40% of blocks of flats with vacancies are challenged by problematic vacancy in urban contexts, too. This implies that structural vacancy is a significant phenomenon all over Finland. Nevertheless, the proportion of completely empty multi-family buildings is rather low even in the most distressed area types. (Article II).

3.1.6 Building sizes

There are significant differences between average areas of buildings of different types, ages, construction materials and locations. The average area of NRB (262 m^2) is notably greater than that of RB (87 m^2). In all, the average sizes range from the 38 m^2 of holiday cottages to the 1263 m^2 of industrial buildings. As the building type and the construction material are connected, it is hardly surprising that in a similar manner, the average area of concrete buildings (1594 m^2) is much larger than that of timber buildings (123 m^2). The oldest and youngest buildings are also, on average, smaller than buildings that originate from the 1950s, 1960s, 1970s or 1980s. (Article I).

The average area is also the larger the more urban the community. This is explained by the significant share of NRB, which are large, amongst the buildings demolished in urban areas. In cities and towns, the average area is more than double the area in the countryside. In growing communities, the average area of demolished buildings is 36% larger than in municipalities with steady-state demographic development and 53% larger than in shrinking municipalities. (Article I).

3.1.7 Summary of reserve characteristics

The obsolete part of the building stock consists of a demolished part and a structurally vacant part, and two-thirds of all vacancy is structural, *i.e.*, problematic. The magnitude of the problematically vacant part is manifold in comparison to annual demolition. The demolition rate is around 0.25% while the residential vacancy rate is 12.7% of the stock. Although the research on vacancy only touched upon RB, it is assumed that the situation is similar with NRB.

However, RB and NRB do differ from each other significantly in many regards. First of all, RB prevail in the existing building stock but the demolished stock is dominated by

NRB (in particular, industrial, public, commercial and office and warehouse buildings). The demolition rate of NRB (0.65%) is fourfold in comparison to that of RB (0.15%), and at the time of demolition, NRB have an average age clearly shorter (43 years) than that of RB (58 years). In all, four-fifths of all demolished floor area is less than 60 years old. NRB are also much larger (262 m^2) than RB (87 m^2), and their material content is different, with a greater share of concrete. This is because demolition of RB is currently dominated by wooden detached houses. Most problematically vacant residential floor area is, however, located in blocks of flats, which are closer to NRB with regard to their size and materials.

Cities that encompass 5% of Finland's area are accountable for 76% of demolished floor area, and the area of demolished buildings is larger there than on average. The demolition and problematic vacancy of blocks of flats is also concentrated on cities.

3.2 Drivers and dynamics in the building stock

3.2.1 Demolition motives

The data distinguishes between four possible demolition reasons: new construction, other reasons, destruction, and abandonment because of decay. Demolitions are a result of conscious deliberation, because destruction or abandonment was behind only a small minority of demolition decisions. New construction was the main motive for demolition, followed by other reasons. In terms of demolished floor area, these two motives were even. Expectedly, new construction dominates the demolition decisions in inner cities, while destruction and abandonment are notable only in the countryside (yet not prevalent). Other reasons prevail amongst the other area types. (Article I).

Even though the demolition motives are quite vague in the data, it was possible to shed some more light on the reported reasons by studying them by decade and by complementing the emerging theory with investigating subsequent new construction (actualized or planned) on the plots of the demolished buildings. Other reasons prevail amongst buildings that originate from the most distant or the most recent decades, whereas new construction dominates the demolition of buildings from the 1940s to the 1980s. Thus, it is possible to theorize that other reasons would, to a certain degree, point at bad physical condition. New buildings would likely not be demolished if it did not come to physical damage, and the physical condition is more likely to deteriorate the older the building is. Mid-20th century buildings, then again, are old enough to fall behind contemporary technical norms and functional expectations. Moreover, when a plot was cleared for new construction, steps towards new construction had also been taken on a clear majority of the plots (64% had new buildings and 8% had permits). When the demolition took place due to other reasons, new construction had been initiated on only one-third of the properties. This could encompass plots that have been cleared for sale (indirectly connected to new construction) and those whose buildings were demolished due to bad condition. (Article I).

3.2.2 Replacement behaviour

In general, the extent of new construction clearly supersedes that of demolition: the latter corresponds to only 22% of simultaneous new production when measured as the number of buildings, or as little as 12% when measured as floor area. Thus, one building was demolished to every fourth or fifth building that was built, and the new buildings were on average larger than the demolished ones. Within the same plot, the number of built buildings was typically the same as the number of demolished buildings. The number of new buildings exceeded the number of old buildings in one-third of the cases, and was below it in only 10%. In the majority of cases, the floor area was increased, but in 15%, it was decreased and in 1%, it stayed the same. (Article I).

In all, over half of the plots were not rebuilt during the examination period (Figure 10). When they were rebuilt, detached houses and blocks of flats were usually replaced with the same building type, while row houses usually gave way for non-residential buildings. Although detached houses were substituted by the same building type in all urban and rural area types, the exchange into non-residential uses was also significant in rural areas. Row houses came off as a yielding residential building type in cities, since they were typically replaced by either blocks of flats or non-residential buildings. Substitution with the same building type was usual only in rural areas, but prevalent merely in the most sparsely populated area type. Blocks of flats were substituted with the same type in community centres, i.e. inner cities and rural towns; they were often exchanged into detached houses in outer cities and non-residential buildings in other area types. As a general rule, the plots were rebuilt more often in central area types than in more remote area types. (Article II). Since the replacement behaviour of NRB was not studied in Article II due to the paper having a focus on RB, it is presented here as new information (Figure 11). The more urban the area, the more prevalent was the exchange into RB. The extent of rebuilding was also lesser than with RB, possibly due to rezoning slowing down the process in cases where the use of the plot changes.

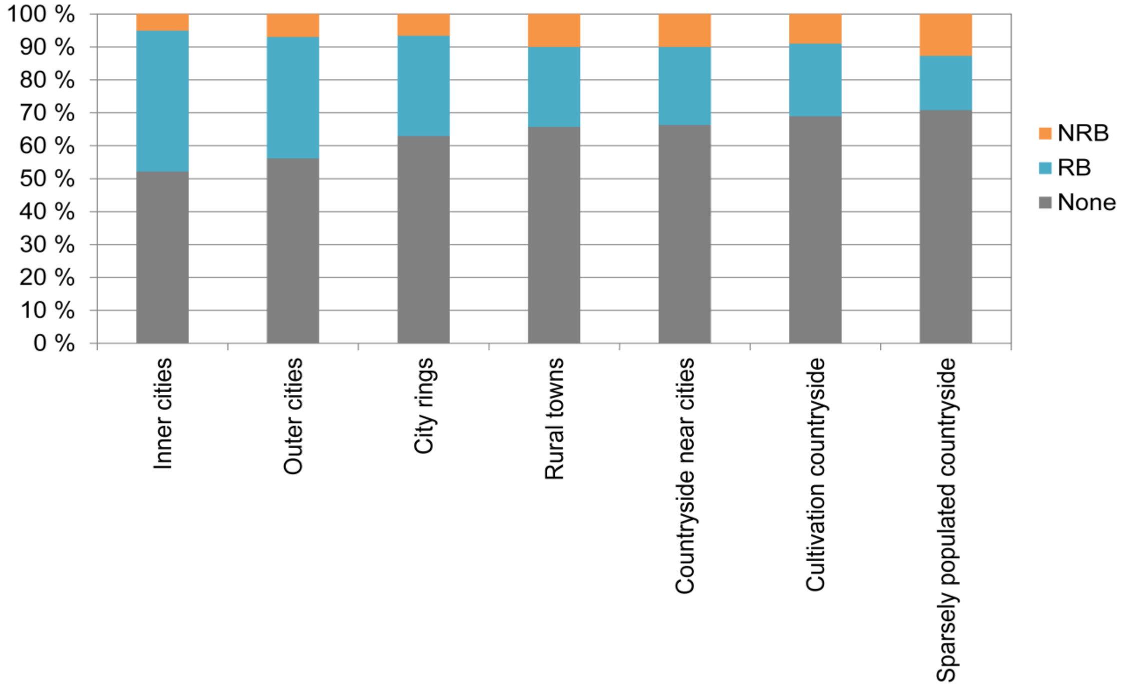


Figure 10. Rebuilding of plots from which RB were demolished (raw data of Article II). RB=residential buildings, NRB=non-residential buildings.

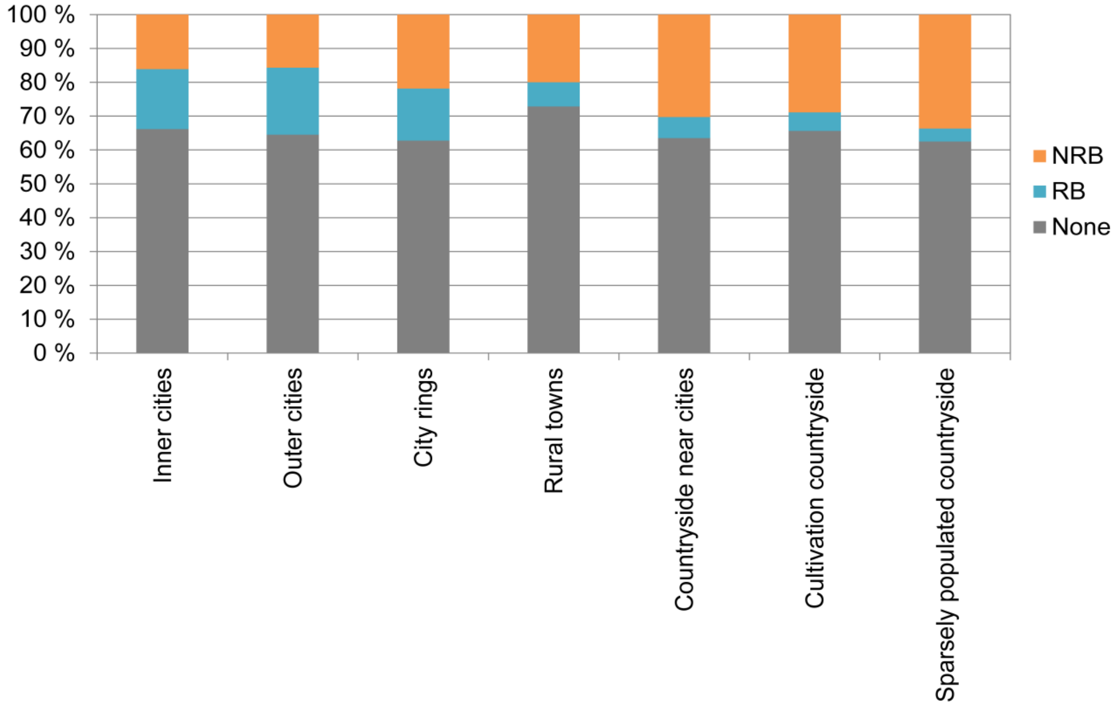


Figure 11. Rebuilding of plots from which NRB were demolished (raw data of Article II). RB=residential buildings, NRB=non-residential buildings.

3.2.3 Influence of building type and ownership structure

The building and tenure types (one owner or multiple owners, owner-occupied or rented) influence the measures that are available for the owner to conduct. Vacancy rates differ between different tenure types: owner-occupied housing has the lowest vacancy rate (9.7%, or 16.0% if calculated as the average of municipalities' vacancy rates) and private rental housing has the highest vacancy rate (18.2%, or 29.0%, respectively). The rate of public-funded rental housing is between them (10.4%, or 25.0%), but the variation of rates is greater than in the case of private rental housing. However, when the tenure and building types of vacant and demolished homes are compared, an overrepresentation of rental flats and detached houses is detected amongst demolished homes. Although the data does not allow distinguishing between non-professional and professional private ownership, the significant proportion of demolition in the stock of private rented flats points at professional ownership. Demolition of owner-occupied housing focuses on detached houses. (Article II).

3.2.4 Relations with population and building stock phenomena

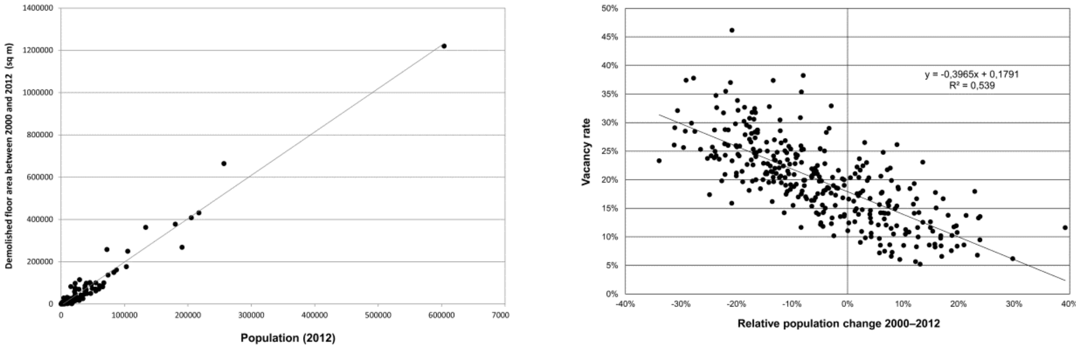
At first, the reader should note that in Finnish communities, the population and its change show currently positive linear correlation (r=0.86). Similar correlations exist also between new floor area and population (r=0.96), population change (r=0.94) and existing floor area (r=0.95). In brief, the larger the community, the larger the population gain, the larger the building stock and the larger the increase in it, and vice versa. This is what regional scientist Timo Aro (2007) has referred to as 'recentralization'.

Similarly, also the amount of demolished floor area correlates with population (r=0.98, Figure 12a), population change (r=0.88), existing floor area (r=0.97) and newly built floor area (r=0.94). The number of demolished homes, too, shows positive linear correlation with population (r=0.91) and population change (r=0.85). Thus, the community size, its demographic development, new construction activities and demolition activities all appear to be interconnected. (Article I). The variables mentioned here refer to absolute, not relative, values, because from resource reserve perspective, absolute values (*e.g.* amount of demolished floor area, number of empty homes) are far more relevant than the relative ones (*e.g.* demolition and vacancy rates).

From local governance perspective, however, the relative values can also be significant. In comparison to how the entire housing stock is distributed, vacant homes are underrepresented in cities and overrepresented in rural areas (see also Figure 9). This denotes that cities have lower vacancy rates than the countryside. Moreover, the shares of buildings with problematic vacancies and buildings that are completely empty are the lower the more urban the area type. This can also be seen by looking at the correlations between vacancy rate and population, absolute population change or the size of the housing stock: they are negative (r=-0.40, r=-0.39 and r=-0.38, in a respective order) and rather power correlation or exponential than linear. In fact, municipalities' gross vacancy rates, as well as those calculated for different tenure types, take different extents but all power correlate negatively with the number of inhabitants. The higher the vacancy rate, the greater the relative loss of population (r=0.73, Figure 12b) and the greater the share of over 65-year-olds (r=0.76, Figure 12c). Higher vacancy rates also denote larger shares of long-term vacant homes (r=0.79, Figure 12d). (Article II).

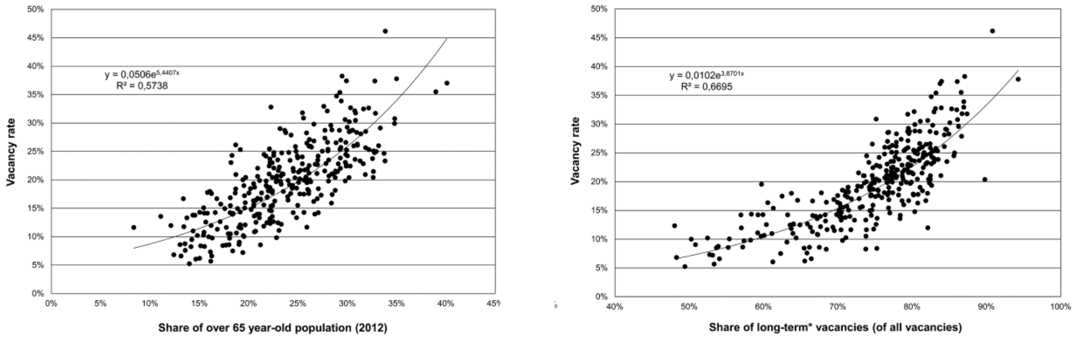
The absolute number of vacant homes, however, shows positive linear correlation with population (Figure 12e), absolute population change or the size of the housing stock (r=0.96, r=0.78 and r=0.97, in a respective order). In other words, the number of vacant homes is large in large growth centres, but their share, *i.e.* the vacancy rate, is lower than in small shrinking settlements, where the overall number of vacant homes is small due to the small size of the housing stocks. (Article II). When it comes to the latter communities, it should be noted that they have not seized to build or to expand the settlements, either (Huuhka, 2014). It would be reasonable to expect high replacement rates in shrinking communities, as that would suggest that new construction does not cater for increased spatial needs but replaces obsolete buildings. The replacement rate, however, shows no correlation whatsoever (r=0.00) with the absolute population change. (Article I). The correlation with relative population change is respectively weak (r=-0.26, Figure 12f). There is a tendency for higher replacement rates in more pronouncedly shrinking communities, but the dispersion is great. (Raw data of Article I).

The overall volume of demolition is small in communities with high vacancy rates, as the correlations between the vacancy rate and demolished homes (r=-0.45, Figure 12g) or demolished floor area (r=-0.36) are negative. This is, again, explained by the small size of the shrinking communities. More interestingly, however, there is no correlation between the vacancy rate and the demolition rate (r=0.02, Figure 12h). High vacancy rates do not denote that a lot of homes would be necessarily demolished. Neither do they mean that no buildings would be demolished at all, as Thomsen and van der Flier (2011) suggest. Thus, any connection between vacancy and demolition is hard to define. (Article II).



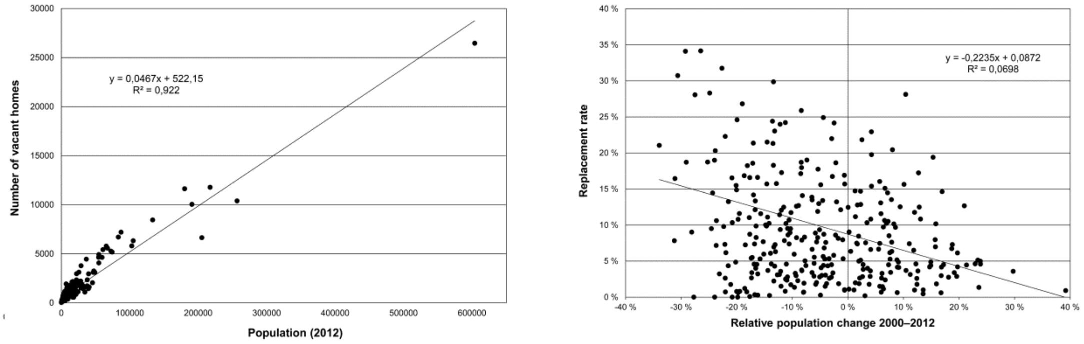
a) population + demolished floor area

b) population change rate + vacancy rate



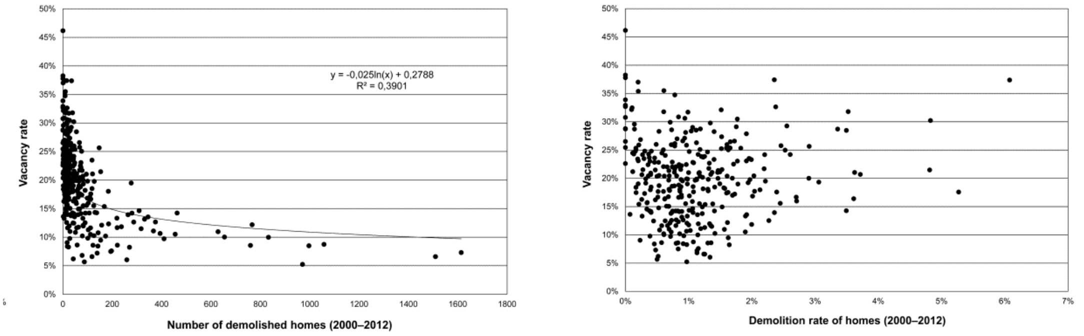
c) share of elderly + vacancy rate

d) share of long-term vacancy + vacancy rate



e) population + vacant homes

f) population change rate + replacement rate



g) demolished homes + vacancy rate

h) demolition rate of homes + vacancy rate

Figure 12. Scatter diagrams depicting correlations or the lack thereof between different demographic and building stock variables. Sources: a) Article I; b–e) Article II; f) raw data of Article I; g–h) Article II.

3.2.5 Summary of drivers and dynamics

Circa half of demolition takes place because of new construction and the other half because of other reasons. The data implies that other reasons are connected to bad physical condition, among other things. Building and tenure types influence the survival of buildings: rental flats (assumingly in professional ownership) and detached houses are overrepresented amongst demolished homes.

When demolished buildings are replaced with new ones, the floor area is typically increased. Plots that were originally in residential use are typically kept that way, but exchange into smaller or larger RB types also exists and depends on the area type. Rebuilding of RB plots takes place more often in urban than rural areas. In the rurality, exchange into NRB increases. Their exchange of NRB plots into RB plots is significant in urban contexts, whereas they are usually kept in their original use in the countryside. NRB plots are rebuilt to a lesser extent than RB plots, likely due to the slowing effect of rezoning processes.

In comparison to how the entire building stock is distributed, vacancy is overrepresented in rural areas. Demolition, on the other hand, is underrepresented there and overrepresented in cities. There is a lack of correlation between municipalities' vacancy and demolition rates, but a clear negative correlation between the number of demolished homes and the vacancy rate. Thus, it is not possible to define a connection between demolition and vacancy in an explicit manner. Similarly, although it is reasonable to expect that in shrinking communities, the role of new construction would be mainly to replace obsolete buildings, this correlation is not very clear, either. A slight tendency for higher replacement rates in shrinking communities was, however, observed.

From resource perspective, the absolute volume of reserves is more decisive than their relative size, although the relative size may be relevant for local decision-making. Like those of new construction, the absolute amounts of demolition (*e.g.* demolished floor area) and vacancy (*e.g.* number of vacant homes) are connected to the sizes of population and building stock, representing a kind of 'economy of scale'. This denotes that significant, geographically concentrated reserves of obsolete buildings are located in cities, even though their vacancy rates are lower than in smaller rural communities. Remarkably, however, the vacancy rates of Finnish communities are quite high and all exceed the limit for normal vacancy (5%). Moreover, the proportion of problematic vacancy is significant even in cities and almost always exceeds that of normal vacancy.

3.3 Characterizing an exemplary cohort

The two previous chapters have dealt with the extents of demolition and vacancy, the share of affected building types as well the materials these buildings withhold, not to mention the regularities these phenomena follow. Whereas those results give the basic material composition of the stock and the understanding on the dynamics also helps to predict future development, these top-down approaches can only result in a very rough material composition, consisting of basic materials such as concrete or timber.

Yet, 'concrete' may be anything from in-situ cast structures to prefabricated parts or cinder blocks of different types and properties (and different spatial implications), just as 'timber' ranges from structural sawn or glued laminated timber with different cross-sections to surface materials such as boards of different kinds as well as other wood-based products. Since there is no all-encompassing database about the materials and structures of the building stock, refining the knowledge top-down is not possible. Instead, proceeding towards more specific understanding requires bottom-up research about the component composition of the stock. Moreover, physical materials and structures are merely media for providing shelters for human needs. The aspired service is, in fact, space, and space is a resource already available in existing buildings. Reusing the resource of space does not necessarily require buildings to be demolished into materials or deconstructed into parts only to be put together again.

Therefore, this chapter makes an effort to exemplify how the component composition or the spatial properties of a given part of a stock can be investigated further. Underlying is an assumption that division into cohorts cannot be avoided, due to major differences in buildings' sizes and their structural characteristics. Because the investigation requires the collection of vast datasets in order for the results to be generalizable, studying all cohorts at once was not realistic. The age-use cohort chosen to act as an example is the 1960–80s blocks of flats.

3.3.1 Component composition of the exemplary cohort

The component composition of the cohort was investigated with regard to reusability from the perspective of dimensions. The data shows that the cohort is, in general, even more monotonous and repetitive than previous studies have implied. The shares of at least partially prefabricated buildings (88%), fully prefabricated buildings (36%), room-size panels (84%) and in-situ cast floors (64%) are clearly greater than in literature (Mäkiö et al., 1994, Hytönen & Seppänen, 2009; Saastamoinen, 2013). (Article III).

In all, there are, on average, 4300 running meters of panel facade or 129 facade panels in a building. 1200 running meters or 46 panels are load-bearing and 3100 running meters or 83 panels are non-load-bearing. In one building, the number of different panels ranges from three to 18, but rarely exceeds six (*i.e.* 1–2 load-bearing panels and 2–4 non-load-bearing panels). The typical situation is one load-bearing panel and three non-load-bearing panels. When the floor is prefabricated, there is on average 1410 m^2 or 180 hollow-core slabs per building. The amount of load-bearing interior walls depends on the floor type, being greater with in-situ cast floors and solid slab panels and smaller with long spanning hollow-core slabs and U-slabs. Alas, the prefabrication of these walls could not be determined from the data. (Article III).

Although the floor height is the same in all buildings (2800 mm, the erstwhile minimum), the room heights (and respectively, the heights of load-bearing parts of panels) vary according to the floor type. The most significant floor types are in-situ cast slabs and prefabricated hollow-core slabs. 64% of the buildings have in-situ cast slabs, whose thicknesses range from 150 to 250 mm. They are typically 200 mm thick resulting in 2600 mm high rooms. 27% of the buildings have 1.2 meter-wide hollow-core slabs, 90% of which are 265 mm thick resulting in a room height of circa 2500 mm. Thicknesses of load-bearing interior walls range from 150 to 220 mm. The thermal insulation of exterior walls is typically 120 mm (mode value), which equals to a U-value of 0.40 W/m2K. (Article III). However, the amount of insulation varies from 75 to 150 mm, depending on the norms in force at the time of the building's construction (Raw data of Article III). Table 4 summarizes the typical properties of components.

Part of building or component	Average or typical value
Prefabricated façade	12 040 m^2 or 4300 rm*
load-bearing	3360 m^2 or 1200 rm*
non-load-bearing	8680 m^2 or 3100 rm*
Façade panels	129 pieces
load-bearing	46 pieces
non-load-bearing	83 pieces
Different panels	3–6 types
load-bearing	1–2 types
non-load-bearing	2–4 types
Prefabricated floor	1410 m^2 or 1175 rm**
Prefabricated floor slabs	180 pieces

Table 4. Typical values in the age cohort (Article III).
*Notes: *) 2.8 m high panels; **) 1.2 m wide slabs.*

In a sample of 26 287 panels (9 387 of which are load-bearing and 16 900 non-load-bearing), 116 different panel widths were observed. However, load-bearing panels are narrower than non-load-bearing ones; the latter typically span the length of a room, whereas the former do not. Load-bearing panels came in 73 different widths, 57 of which were encountered in more than one building. Non-load-bearing panels exhibited 98 different widths, and 64 of them recurred in multiple buildings. However, 70% of all panels come in the 20 most common widths; the top ten widths cover more than half of the panels and the top five widths cover a third. Moreover, the occurrence of the most common widths exceeds their share. For instance, the 3000 mm non-load-bearing panel occurs in every third building, although its share of all panels is only 10%. Rounding the panel widths to the nearest 100 mm nearly halved the total number of widths (68). Hollow-core slabs, then again, represent the lengths of one, two or three rooms, ranging from 2400 to 10 800 mm. In all, there are 74 different lengths to them in a sample of 13 508 slabs, and rounding to the nearest 100mm does not reduce the number of lengths significantly (68). (Article III).

There are three main types of exterior wall panels: blind panels, panels with one window and balcony back wall panels that are equipped with a window and a door. Load-bearing panels are typically blind, whereas the two other types are representative to non-load-bearing panels. When the load-bearing function and the type and width of panel are considered, there are, in all, 357 of such combinations, *i.e.* individual panels. However, the 20 most common of them cover as much as 50% of all panels, and the top ten in each panel type account for a clear majority (64–83%) of the panels of that type. (Article III).

The widths of non-load-bearing panels were investigated with regard to compatibility with current room width recommendations (Figure 13). 99.5% of the panels were found compatible with recommendations for at least some of the spaces. 86% of the panels adhere to the recommended widths for one or more rooms and 14% are even wider than that. Most panels are compatible with two-person bedrooms and dining rooms, whereas one-third complies with living rooms, kitchens and one-person bedrooms. The panels also meet the current requirement for the minimum room height (2500 mm). They do not, however, fulfil the present requirement for minimum floor height in blocks of flats (3000 mm). (RakMK G1, 2005, p.4–5). Furthermore, the 265 mm hollow-core slab does not meet the current norm for impact sound insulation between apartments, in force since 1998. In addition, 53% of the studied interior walls do not fulfil the current norms for acoustics, which determine that walls separating flats should be at least 180 mm thick. (Lietzén & Kylliäinen, 2014). Due to these reasons, reuse in blocks of flats is out of the question. As there is no minimum floor height requirement for detached, semi- detached, terraced or row houses (RakMK G1, 2005, p.4–5), the reuse of the old panels is possible in this kind of housing. Reusing hollow-core slabs and interior walls thinner than 180 mm is also possible within a single apartment. Moreover, the amount of thermal insulation in exterior wall panels does not comply with the present-day norm of U-value 0.17 W/m^{2}K. For the mode value of 120 mm of insulation, additional 150 mm of mineral wool is necessary on top of the panels if they are to be reused in warm constructions. (Article III).

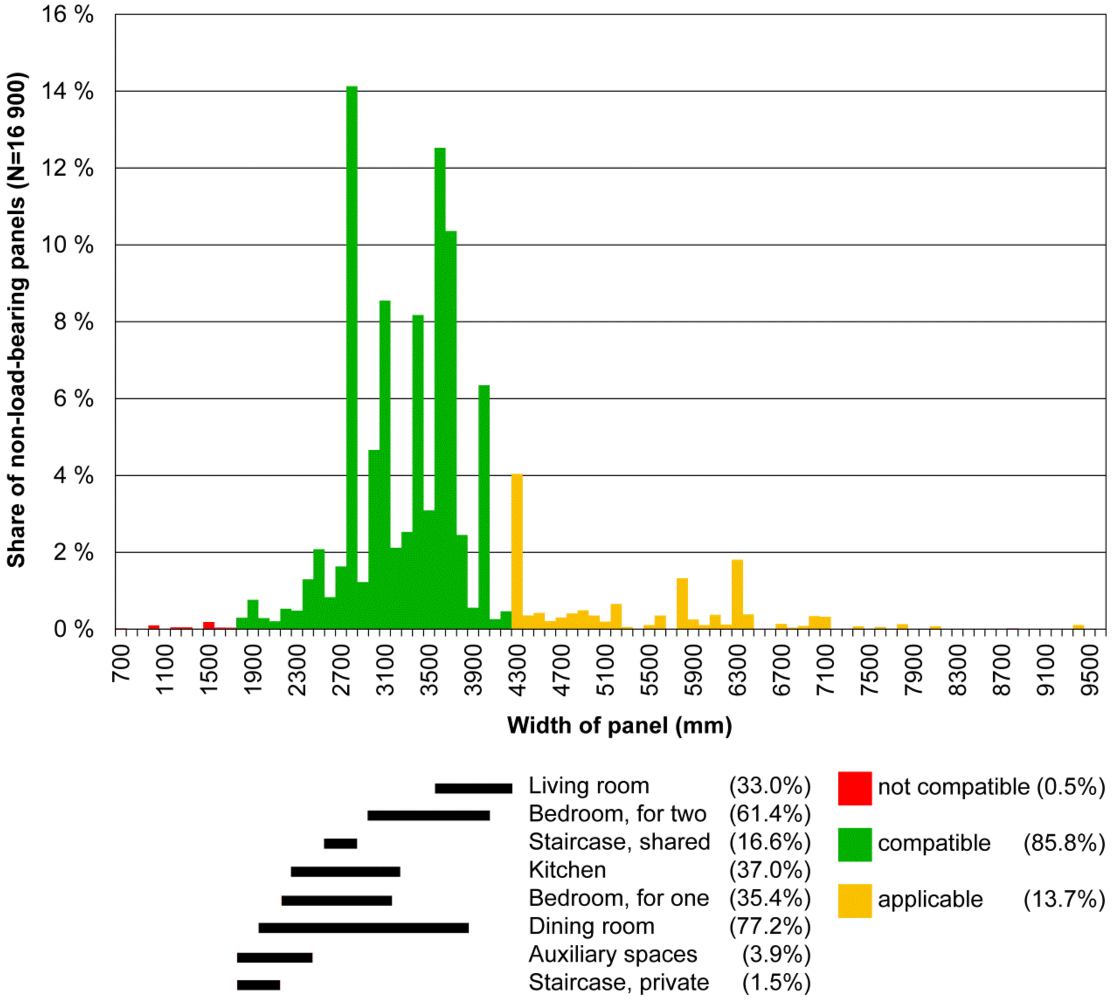


Figure 13. Width distribution of non-load-bearing room-size façade panels and the compatibility of the dimensions with current room width recommendations (Article III).

3.3.2 Built form of the exemplary cohort

The typological investigation into the built form of the blocks of flats of the same era revealed 18 recurring flat types that cover 80% of flats in the data (Figure 14). 13 of them are subtypes, *i.e.* variations of 10 basic layouts, differing from each other only in their internal configuration, whereas five types are self-standing 'main' types that have no subtypes.

The first flat type of a given flat size (coded 'X–1') is always dominant amongst flats of that room count; and the first of the subtypes of each main type (coded 'X–XA') is always clearly more prevalent than the other variations. There are as little as three studio types (one main type and two subtypes of another main type); that cover 80% of all studios; seven two-room flat types (one main type and six subtypes based on two other main types) that cover 83% of flats with the respective room number; five three-room flat types (two main types and three subtypes of a third main type) covering 74%; and three four-room types with a coverage of 54% (one main type and two subtypes of another main type).

Figure 14. Typical flats in 1960–80s apartment blocks (Article IV).

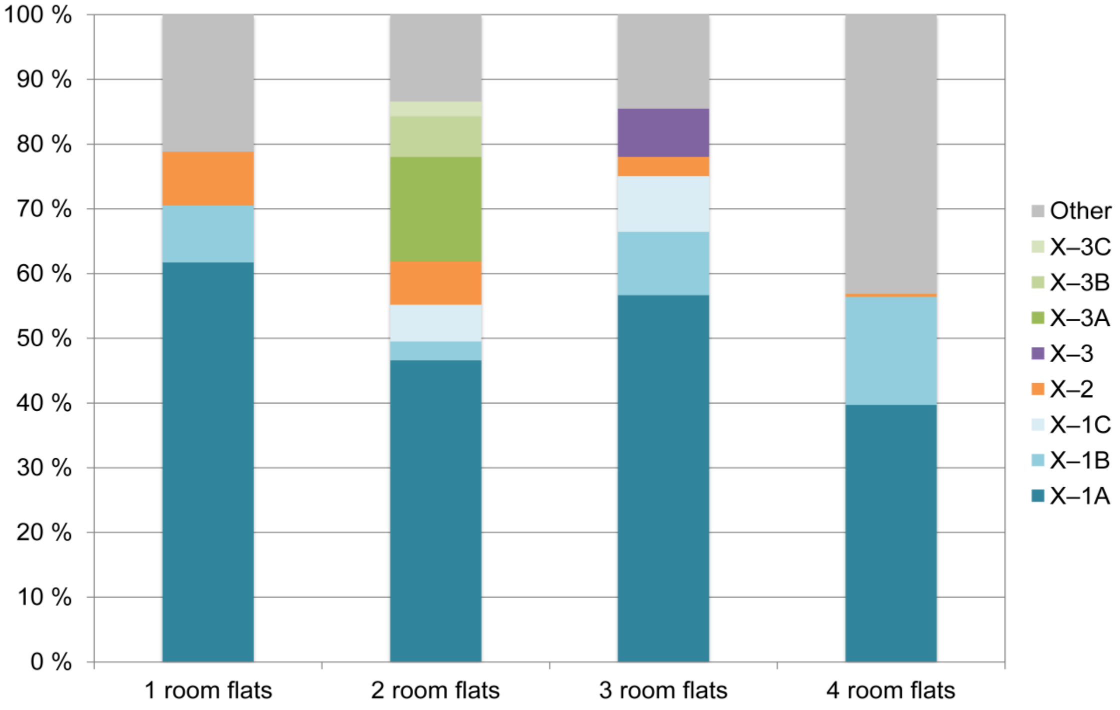


Figure 15. Prevalence of flat types in slab blocks (Article IV).

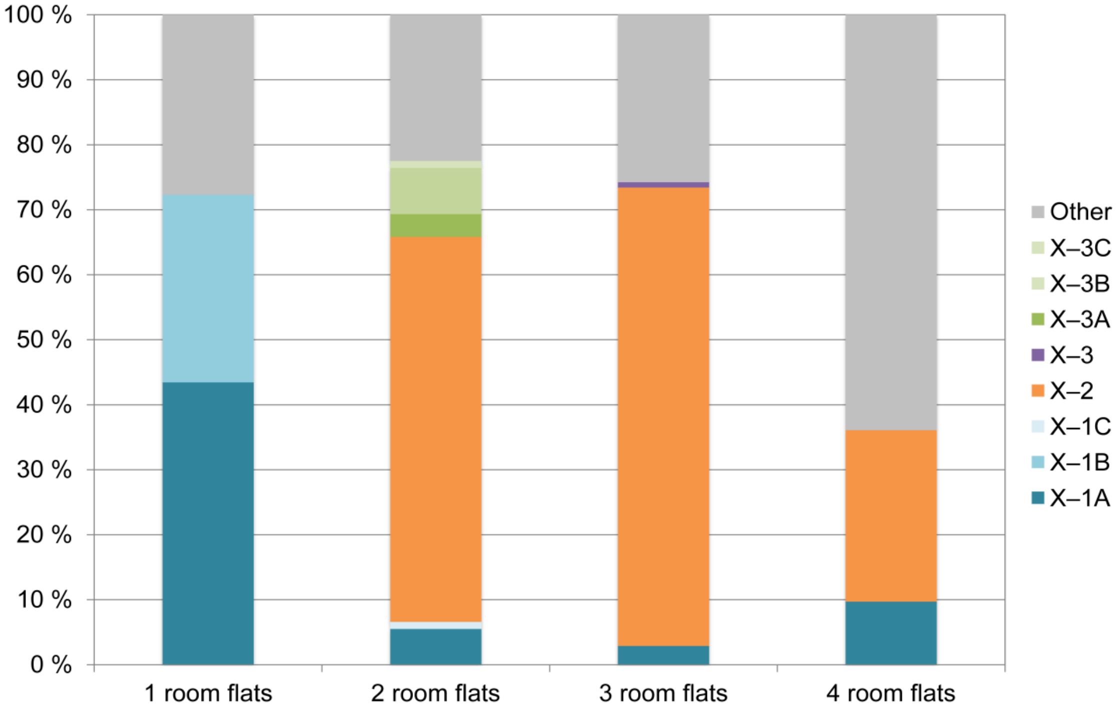


Figure 16. Prevalence of flat types in tower blocks (Article IV).

The coverage of the most common main types (internal variation ignored) is, in a respective order, *i.e.* from the smallest room count to the largest, 71%, 41%, 53% and 49%. The coverage of the most common single type is, 56%, 35%, 40% and 35%, respectively. (Article IV). The more prevalent the flat size (the room number) in the sample, the greater the share of flat types within it: two-room flats are most prevalent and have the highest proportion of identified types, whereas four-room flats are relatively rare and exhibit the lowest type coverage. Figures 15 and 16 elaborate on the prevalence of the types in slab and tower blocks in more detail.

Some larger flat types are derivative of smaller types. 2–1 is related to 3–1, 3–3 as well as 4–1; and 2–2 is the basis for 3–2 and 4–2. Moreover, many of the flats that compose the remaining 20% that is not covered by types, including the rare flats with five or more rooms, are also clearly variations of the identified types. In the current study, they have not been common enough to justify forming another type or subtype, but this could change if the sample size was increased. (Article IV).

As seen in Figures 15 and 16, most flat types are more characteristic to either slab blocks of tower blocks. Main types 1–2, 2–1, 3–1, 3–3, and 4–1 are typical to slab blocks, whereas 2–2, 3–2 and 4–2 occur almost exclusively in tower blocks. Main types 1–1 and 2–3 appear in both, with their first subtype being more common in slab blocks and the other subtypes in tower blocks. The flat types also have a characteristic position within the building mass. 1–1, 1–2 and 2–3 have only one exterior wall and situate, thus, in the middle of the facade, whereas 2–1, 3–1, 3–3, and 4–1 are always located in the end of a staircase unit, and 2–2, 3–2 and 4–2 occur in the corners of a tower block. In addition, certain flat types tend to neighbour each other. In slab blocks, typical combinations are 2–1, 1–1 and 3–1; 2–1 and 3–1; 2–1, 2–3 and 2–1; 3–1 and 3–1; 3–3, 1–1, 1–1 and 3–3; 3–3, 2–3 and 3–3; and 3–1 with 4–1. In tower blocks, 2–2, 1–1 and 2–2 occur together with 3–2 and 3–2 above them in the plan. Figure 17 presents the same information in a visual form. The reader should note, however, that these combinations are not equally common; for instance, flats of the type 3–3 are quite rare whereas those of the type 2–1 are very common, which makes also the combinations with 2–1 much more prevalent than those with 3–3. (Article IV). Later derivative research that lists the prevalence of the staircase unit types, has also added four new types to this list, that is, 2–1, 1–1 and 2–1; 2–1, 1–1, 1–1 and 2–1; 3–1, 1–1 and 3–1; and 2–1, 1–1 and 4–1 (Achrén, 2015; Huuhka, 2015).

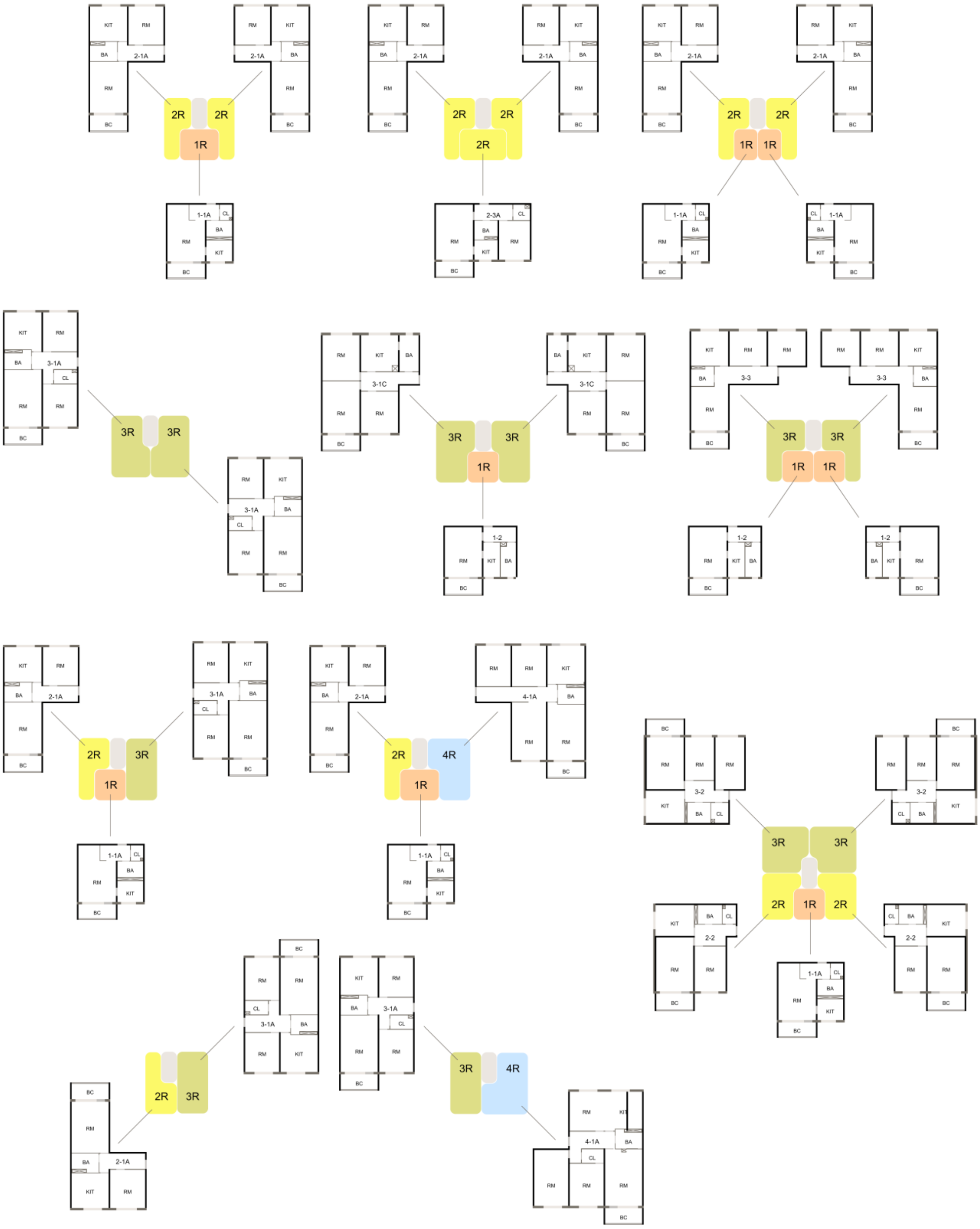


Figure 17. Characteristic combinations of flat types in staircase units (Huuhka, 2015).

3.3.3 Summary of the characterization of the cohort

Although the examined cohort is not standardized, both its components and its flat plans exhibit a highly repetitive character. The cohort was known to have a high degree of prefabrication, but its extent is even greater than literature implies, reaching up to 88% of the buildings in the sample.

On average, the blocks of flats of the examined cohort withhold 129 façade panels and 180 hollow-core slabs, when both the walls and the floors are prefabricated. Most often, however, the floors are in-situ cast. The number of different kinds of façade panel types in one building is, in most cases, not more than six. The prefabrication of interior walls could not be deciphered, which is why these panels could not be quantified, either.

Although the panels and slabs exhibit dozens of widths and lengths, the 20 most common panel widths cover as much as 70% of all panels. The most common widths also occur in the buildings more often than their frequency of all panels imply. For example, the most commonly occurring panel is a 3000 mm wide non-load-bearing panel, which covers 10% of all panels but occurs as frequently as in every third building. When the load-bearing function and the type of the panel (with / without different kinds of openings) are taken into consideration, the number of individual panels lands at 357. Remarkably, the 20 most common of them cover as much as 50% of all panels. Almost all panels (99.5%) can be compatible with current room width recommendations. Due to regulation regarding the floor height and acoustics, however, the use of reclaimed panels is restricted to detached, semi-detached, terraced and row houses, given that supplementary thermal insulation is added to meet the present energy requirements.

As for the spatial composition of the buildings, 80% of the flats of the cohort were found to consist of ten basic layouts. Five of these layouts do not have internal variation in the placement of functions, whereas the remaining five divide into 13 subtypes with slightly differing internal configurations. Many larger flat types are derivative of smaller types, and many flats not covered by the typology are also rarer variations of these types.

Each room count has one clearly dominant flat type, covering 35–56% of flats of the room count in question. One-room flats as an exception, slab and tower blocks have their own distinctive flat types. When the prevalence of flat types is examined separately for the aforementioned building types, the share of the dominant flat type rises, in most cases, up to 40–71%. The flat types exhibit specific positions on façades and are neighboured by particular other types. This enabled distinguishing certain flat combinations, or staircase unit types. Together, the flat and staircase unit types portray the spatial nature of the examined cohort in a reasonably comprehensive manner.

3.4 Resource reserve quantification

3.4.1 All building types

The exact numbers and floor areas of demolished buildings are provided in Chapter 3.1 (see e.g. Table 3 and Figures 6, 8 and 9). Figure 18, however, elaborates on the floor areas of demolished buildings by more specific building types. In order to be meaningful, these kinds of figures need to be related to those of new construction. As already stated, the overall volume of new construction in Finland clearly exceeded that of demolition during the examination period, and new construction has continued even in shrinking communities. When the matter is looked at on the scale of the municipalities, the situation is the same: new construction supersedes demolition in every single Finnish municipality. When the municipal-level investigation takes into consideration building types in nine categories (categorization had to be adapted to that used in statistics, Appendix II), only 8–25 municipalities out of 320 emerge, depending on the building type, where the volume of demolition in that building type exceeds that of new construction (Table 5). The overrun is insignificant in most cases. From this point of view, new construction is a plausible sink for the parts and materials from the demolished buildings at the national as well as the local scale. Since the need for the specific building types also supersedes demolition, continued use may also be a viable alternative. (Article I).

Building category	**Number of municipalities (N=320), where**	
	New construction ≥ demolition	**New construction < demolition**
Detached houses	320	0
Row houses	306	14
Blocks of flats	306	14
Holiday cottages	310	10
Commercial and offices	295	25
Public buildings	297	23
Industrial and warehouses	312	8
Agricultural buildings	310	10
Transport buildings	305	15

Table 5. Relations of newly constructed and demolished floor area of different building types (Raw data of Article I).

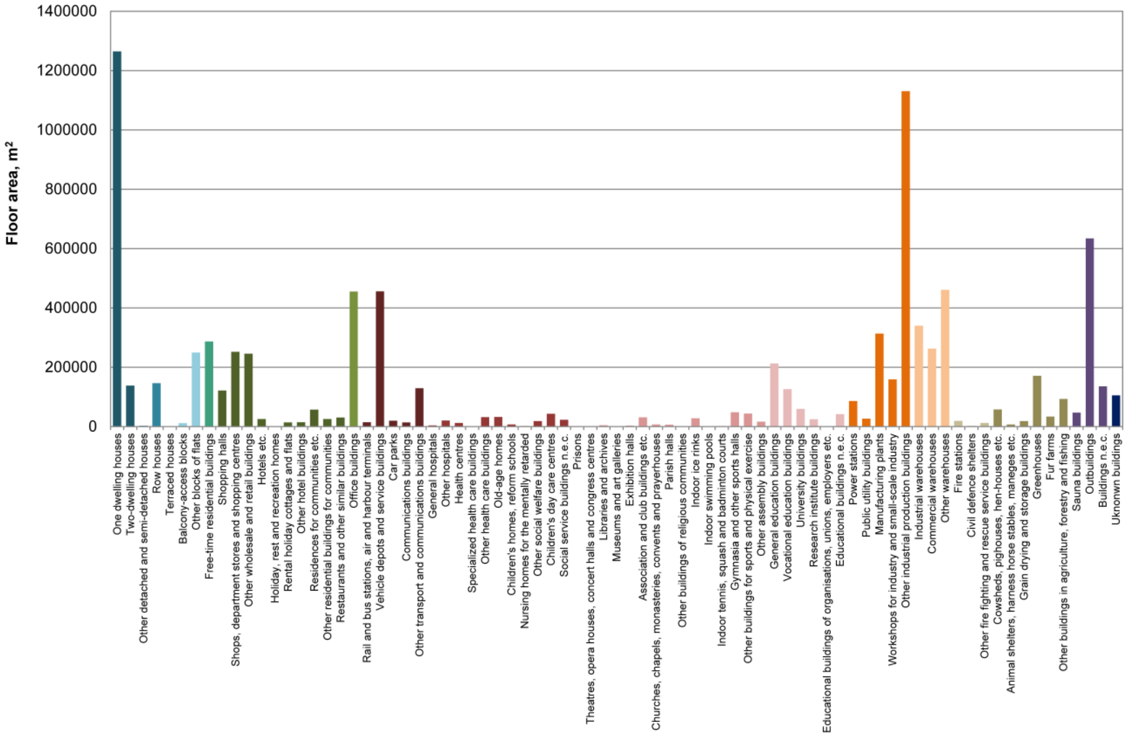


Figure 18. Floor areas of demolished buildings in all building classification categories (Appendix I), 76 building types in total, plus buildings whose type is unknown. Note: Colour code follows that of Figure 4 with the exceptions that Figure 4 omits free-time residential buildings (turquoise), firefighting and rescue service buildings (grey), agricultural buildings (brown) and unknown buildings (navy). (Raw data of Article I).

3.4.2 Residential buildings

RB may also be investigated with regard to the size of the vacant stock. The exact numbers of buildings and homes as well as their floor areas are, again, available in Chapter 3.1 (Table 3, Figures 6, 8 and 9), but the current chapter relates them to the magnitude of new construction and demolition. The annual volume of the long-term or problematically vacant part of the stock is manifold in comparison to both the simultaneously erected and the demolished part of the stock. In mid-2014, the number of long-term vacant homes was 8.5 times the number of homes built in 2013 or 111 times the annual average number of homes demolished (calculated from the previous 13 years). By building type, the reserve of homes was 17 times the yearly new production for detached houses, 5 times for row houses and little under 4 times for blocks of flats. With regard to demolition, then again, the figures are notably greater: 118 times the yearly demolition of homes for detached houses, 103 times for row houses and 154 times for blocks of flats. This is to say that at the current pace, it would take more than a century to demolish the long-term vacant homes. In terms of floor area, the proportion of multi-family buildings with problematic vacancies appears more significant than if only vacant homes are observed. Their extents are, in a respective order (detached houses - row houses - blocks of flats) 8, 16 and 12 times the annual production and 132, 469 and 246 times the yearly demolition of floor area. The reader should, however, remember that even the problematically vacant multi-family buildings also contain many occupied homes. (Article II). Figure 19 elaborates on the relation of annually newly constructed and problematically vacant floor area of different RB types on the municipal level.

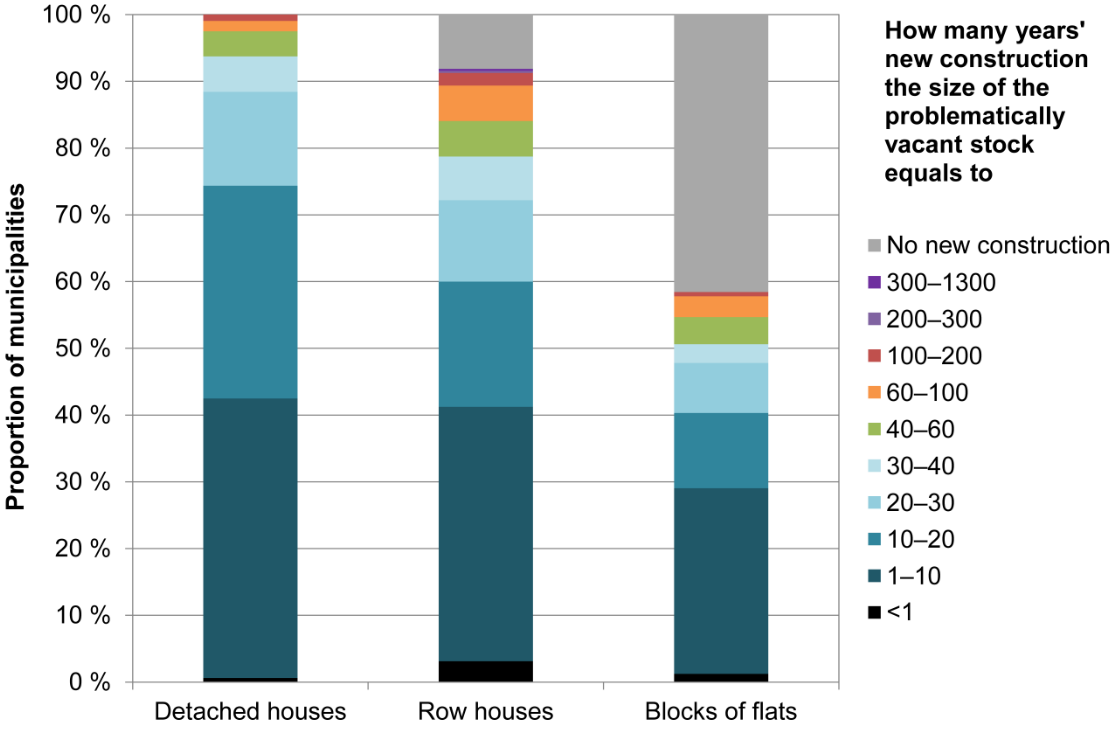


Figure 19. Extents of municipalities' reserves of problematically vacant homes in different building types in comparison to annually newly constructed floor area (average from 2000–12). (Raw data of Article I; Raw data of Article II). Note: The problematically vacant floor area used in this calculation covers only the area of vacant homes in buildings with problematic vacancies, whereas the area of new construction contains the corridors and other common facilities. Therefore, the compared data are not perfectly commensurable, and the results are approximate

3.4.3 Exemplary cohort

Existing part

Since Chapter 3.3 focused only on the characterization of the composition of the exemplary cohort, it needs to be quantified separately, unlike the demolished and vacant parts of the stock. Similarly to them, however, the size of the exemplary cohort is also proportioned here with that of the entire stock. Although the samples used in the research contain buildings from 1968 to 1985, in this quantification it is assumed that the research material represents the entire decades from 1960 to 1989. This is because conventions in architecture and construction neither start nor end abruptly. For instance, some of the identified flat types appear already in plans of 1950s buildings, included in Mäkiö et al. (1990: 100–16). Furthermore, the same plans could also have been in use in row houses built with similar construction technologies.

In all, the cohort of 1960–80s blocks of flats contains 30 378 buildings, which represent 51% of all Finnish high-rise housing construction in terms of the number of buildings and 54% in terms of the floor area (Statistics Finland, 2015). The number of flats in them is 725 207 (Kakko, 2011: 120–1), equaling to 57% of all flats and 25% of all homes. The cohort divides into different flat sizes as shown in Table 6. When full generalizability of the flat typology is assumed, 80% or circa 580 000 of them belong to one of the 18 flat types identified in this study, as shown in Table 7. This calculation demonstrates that in all, one-fifth of Finnish homes conform to the typology. Moreover, almost half (46%) of all flats follow the typology, and nearly every tenth flat belongs to the most common of the types, the 2–1A.

If it is assumed that the entire cohort’s degree of prefabrication follows the results of this study, 84% of the buildings would have prefabricated square panel facades and 27% would have hollow-core slabs (Article III). Thus, 25 517 buildings would have panel facades and 8202 of them would also have hollow-core slabs. Using data from Table 4, Table 8 estimates the quantities of panels and panel surfaces in them.

Room count	Proportion (%)	Number of homes
1 room	20.5	148 667
2 rooms	44.9	325 617
3 rooms	28.9	209 584
4 rooms	5.5	39 886
5 rooms or more	0.2	1 450

Table 6. Room count distribution in the cohort (Raw data of Article IV).

However, this assessment can be expected to exaggerate the extent of the reserve more significantly than the flat type quantification, because the degree of prefabrication was notably lower in the early 1960s, be it that it kept rising the entire 1980s. Moreover, the calculation ignores possible losses of components resulting from existing damage or damage occurring during deconstruction. As noted earlier, the reuse of these panels is currently limited to low-rise low-density housing due to sound insulation requirements. (Article III). Detached houses, for instance, account for one-third of annual new construction of homes in Finland. When the panels of an average block of flats could make up nine houses, the entire stock could contribute to circa 230 000 houses. This represents roughly the construction needs of two decades at the current pace.

Flat type	Number of flats	Proportion of all flats (%)	Proportion of all homes (%)
1-1A	83 848	6,6	2,9
1-1B	21 854	1,7	0,8
1-2	8 622	0,7	0,3
2-1A	113 965	9,0	4,0
2-1B	6 837	0,5	0,2
2-1C	14 327	1,1	0,5
2-2	70 333	5,5	2,5
2-3A	40 702	3,2	1,4
2-3B	21 165	1,7	0,7
2-3C	6 512	0,5	0,2
3-1A	84 252	6,6	2,9
3-1B	14 251	1,1	0,5
3-1C	12 575	1,0	0,4
3-2	49 671	3,9	1,7
3-3	11 317	0,9	0,4
4-1A	13 920	1,1	0,5
4-1B	5 623	0,4	0,2
4-2	1 834	0,1	0,1
All types	581 608	45,6	20,2

Table 7. Amounts of flat types in the entire cohort and their proportions with regard to all flats and all homes from all times.

Panel type	Panels (pcs)	Surface (rm)	Surface (m^2)
Load-bearing façade panel	1 173 782	30 620 400	85 737 120
Non-load-bearing façade panel	2 117 911	79 102 700	221 487 560
Hollow-core slab	1 476 360	9 637 350	11 564 820

Table 8. Quantification of panels and panel surfaces in the entire cohort.

Problematically vacant part

The number of buildings in the exemplary cohort that have problematic vacancies is 6982, which equals to 23% of the entire cohort. They have 180 230 flats in total, 142 257 of which are occupied and 37 973 of which are vacant. (Raw data of Article II). Thus, the number of unoccupied flats represents only 5% of the entire stock but 27% of the flats of the affected buildings. Using the same assumptions as the previous chapter, 5685 of these buildings would have square panel facades and 1885 would have hollow-core slabs. Table 9 estimates the quantities of the flat types and Table 10 those of the panels, which could make up more than 50 000 detached houses.

Flat type	Number of flats	Number of occupied flats	Number of vacant flats
1-1A	20 837	16 447	4 390
1-1B	5 430	4 286	1 144
1-2	2 142	1 691	451
2-1A	28 322	22 355	5 967
2-1B	1 699	1 341	358
2-1C	3 560	2 810	750
2-2	17 478	13 796	3 682
2-3A	10 115	7 984	2 131
2-3B	5 259	4 151	1 108
2-3C	1 617	1 277	340
3-1A	20 938	16 527	4 411
3-1B	3 541	2 795	746
3-1C	3 124	2 466	658
3-2	12 343	9 743	2 600
3-3	2 812	2 220	592
4-1A	3 458	2 730	728
4-1B	1 397	1 103	294
4-2	455	359	96
All types	144 527	114 081	30 446

Table 9. Flat types in buildings of the cohort with problematic vacancies.

Panel type	Panels (pcs)	Surface (rm)	Surface (m^2)
Load-bearing façade panel	261 510	6 822 000	19 101 600
Non-load-bearing façade panel	471 855	17 623 500	49 345 800
Hollow-core slab	339 300	2 214 875	2 657 850

Table 10. Quantification of panels and panel surfaces in blocks with vacancies.

Demolished part

Between 2000 and 2012, only one hundred buildings with 1857 flats were demolished from the exemplary cohort (Raw data of Article I). Both the number of buildings and the number of flats represent 0.3% of their existing stocks. 21% of blocks of flats demolished during that time belonged to the exemplary age cohort, which is clearly less than their proportion of all apartment buildings (51%). Tables 11 and 12 quantify the numbers of demolished flat types as well as the panels from the 84 buildings with square panel facades and 27 buildings with hollow-core slabs, which could have contributed to the construction of circa 800 detached houses.

Flat type	Number of demolished flats
1-1A	214
1-1B	55
1-2	22
2-1A	291
2-1B	17
2-1C	36
2-2	179
2-3A	104
2-3B	54
2-3C	16
3-1A	215
3-1B	36
3-1C	32
3-2	127
3-3	28
4-1A	35
4-1B	14
4-2	4
All types	1 479

Table 11. Flat types in demolished blocks.

Panel type	Panels (pcs)	Surface (rm)	Surface (m^2)
Load-bearing façade panel	3 864	100 800	282 240
Non-load-bearing façade panel	6 972	260 400	729 120
Hollow-core slab	4 860	31 725	38 070

Table 12. Quantification of panels and panel surfaces in demolished blocks.

3.4.4 Summary of resource reserve quantification

The total volume of new construction exceeded that of demolition in all Finnish municipalities, the growing as well as the shrinking ones. Building types considered, new construction superseded demolition in 92–100% of the municipalities.

The volume of the residential stock with problematic vacancies is manifold to those of new construction and demolition. The extent of the reserve depends on the building type and the municipality. Compared to the current pace of demolition, it would take more than a hundred years to demolish the problematically vacant or underutilized part of the residential stock. In more than half of the municipalities, the reserves of floor area equal to the needs of 10 years or more regardless of the building type. In many municipalities, however, the size of the reserve can represent the needs of several decades.

The exemplary age-use cohort of 1960s–80s blocks of flats makes up more than half of all Finnish flats and one-fourth of all homes. 23% of the entire cohort is affected by problematic vacancy. The number of vacant homes equals to 5% of the whole cohort but 27% of the involved buildings. Nevertheless, only 100 such buildings, or 0.3% of the entire cohort, were demolished between 2000 and 2012.

Using the results from the previous chapter, it was possible to quantify the numbers of flats belonging to the identified flat types as well as the reserves of concrete panels in these buildings. This calculation demonstrates that one-fifth of all Finnish homes and nearly half of all existing flats conform to the identified types. In all, the components embedded in the existing buildings of the cohort equal to nearly two decades' new construction in the category of detached houses. The reserve in the problematically vacant part represents the construction needs of detached houses for circa four years.

3.5 Results synthesis

The findings increase understanding on the composition of the Finnish building stock as well as its dynamics. The obsolete parts of the stock were described statistically for the first time using empirical data (Chapter 3.1). The relations thereof to each other as well as new construction and the size of the stock were also discussed (Chapters 3.2 and 3.4). The investigation was taken further concerning the composition of one exemplary cohort (Chapter 3.3), which enabled quantifying the resources in the existing, problematically vacant and demolished parts of the cohort (Chapter 3.4).

Major differences were observed with regard to demolished RB and NRB. NRB are larger, they have a greater demolition rate and a shorter average age at the time of demolition. Moreover, NRB dominate demolitions although RB prevail in the existing stock. Proportioning the volume of demolition to new construction revealed that new construction could act as a sink for materials or parts from demolition in practically all Finnish municipalities. Moreover, two-thirds of all residential vacancies were found to be structural, *i.e.* problematic, and their volume was manifold compared to demolition. In more than half of the municipalities, the structurally vacant part of the residential stock also equalled to the construction needs of more than a decade, or even several decades. Its demolition would, however, take more than a century at the current pace.

The relation between demolition and vacancy could not be defined unambiguously. Demolition is geographically concentrated on cities; vacancy is overrepresented in rural settings. Whereas vacancy rates correlate expectedly with a number of other indicators, they do not correlate with demolition rates of homes. In absolute numbers, the sizes of both these reserves for materials or services are connected to the size of the population and the building stock, denoting that greatest reserves can be found in cities. This is despite their generally lower vacancy rates, which do, however, clearly supersede the limits for normal transaction vacancy.

The cohort investigated in an exemplary manner was found to exhibit a more repetitive character than expected. Investigating its flats enabled defining a typology of 10 basic types (or 18 subtypes) that covers as much as 80% of its flats. Although the concrete panel composition of the cohort is slightly more variable, the 20 most common façade panels (load-bearing function, openings and width considered) were found to cover as much as 50% of all panels. The reserves in the cohort's existing, problematically vacant and demolished buildings were quantified in terms of flat types and numbers of panels and panel surfaces.

4 Discussion

4.1 Implications

4.1.1 Theoretical implications

In introducing the need for a paradigm change, Kohler and Hassler (2002) argued that until then, building stocks had not been researched systematically. The lack of systematicness is also evident when it comes to the research on the Finnish building stock. All Kohler and Hassler's (2002) observations about the state of research on building stocks apply to the Finnish context: data is better on housing; NRB are largely neglected; research is sectorized, with narrow objectives; and the results are often not generalizable. Unlike many countries, Finland, however, has relatively good basic data about the composition of the stock.

Taking advantage of this data as well as newly collected research material, the current dissertation has introduced the new paradigm to the research of the existing stock in Finland. The findings demonstrate the advantages of using large datasets that lead into generalizable results, contrary to isolated case studies. Although building stock research starts off from a top-down perspective, the dissertation shows that both top-down and bottom-up approaches can result in generalizable results. In fact, since the availability of all-encompassing (top-down) data is limited, both approaches are equally necessary.

The key objective in building stock research is supporting sustainable management and long-term preservation of the built environment (Kohler, Steadman & Hassler, 2009). This requires understanding the dynamics of the stock, that is, drivers related to the replacement of buildings. The lack of data on buildings at their end-of-life phase is even more critical than that of other parts of the stock. (Thomsen, Schultmann & Kohler, 2011). Therefore, most research on this topic has relied on theorizing and models.

This dissertation, on the other hand, has employed the Finnish BDR data to investigate obsolete, that is, demolished and problematically vacant, parts of stocks. Many of the findings from the research support current theories and some of them can also help to validate or develop existing stock models. The research, for instance, illustrates that assumptions about the shorter lives of NRB are justified, and that the mortality in the building stock is dynamic, not static or variable. Thus, NRB seem indeed to need different approaches than RB, as suggested by Sartori et al. (2008), and any approaches employing assumptions relying especially on static mortality appear to be fundamentally flawed and should preferably be relinquished.

Moreover, this dissertation has been amongst the first to discuss the complex relationship between demolition and vacancy, and it has done so based on real data. Whereas vacancies are monitored and investigated intensively in housing market research, their role is currently largely neglected in the study of building stock dynamics. The findings on the location, composition and dynamics of the obsolete parts of stock can act as the basis for assessing the magnitude of material deposits and for the future modelling of metabolic behaviour. As Meinander and Mroueh (2012: 19) have observed, there is, however, a lack of data at the unit level on the material composition of the stock that currently prevents these kinds of analyses from taking place. This dissertation has also started to bridge the gap by investigating the component composition of one exemplary cohort. The approach did not only result in an assessment of the cohort's raw material content but elaborated on the types of structures and building parts, as follows from EU's targets to move up on the waste hierarchy and to refine recycling and reuse of physical resources. The same method can, and should, also be used for studying other cohorts, in order to properly quantify the potentials of the existing stock as a deposit of spaces and components.

A focal aspect in shifting to more sustainable building stock management is the overall deceleration of urban metabolisms, that is, decoupling the service provision of buildings from the use of materials (Pauliuk & Müller, 2014). Therefore, already existing buildings should not only be seen as deposits of materials or components, but as reserves of possibly usable space (Kohler & Hassler, 2002; Thomsen & van der Flier, 2011). Using the exemplary cohort, this dissertation has demonstrated how the spatial arrangements in a cohort can be investigated and generalized, providing the basis for evaluating the cohort's adaptation and modification potential. The introduced method is appropriate for researching other cohorts, too, although due to their different nature, NRB cohorts may also require other graph theoretical approaches.

4.1.2 Practical implications

As the research presented herein represents basic research on the building stock, its practical implications are not as immediate as its theoretical ones. Since the objective of building stock research is, eventually, to support sustainable stock management (Kohler, Steadman & Hassler, 2009), the practical implications of the current study are also mostly related to the insights it can provide for administration and decision-making.

Kohler, Steadman and Hassler (2009) remind that public policy-making should base on evidence. Systematic analyses of building and housing stocks and their state of usage do not currently underlie national building stock policies in Finland, neither do they inform Finnish municipalities' zoning and planning decisions. Thus, public decision-making would benefit from understanding the magnitude, location and qualities of reserves in the existing, vacant and demolished parts of both national and local stocks and acknowledging what could be done with the obsolete parts of the stock, were they reconsolidated. With two-thirds of Finnish municipalities shrinking in terms of inhabitants, many of them would benefit from exchanging the growth paradigm into a more stock-centred one. As Rajaniemi (2006) has demonstrated, the growth paradigm can have detrimental effects for the quality of their built environments.

Continuing new construction vigorously when extensive amounts of vacant spaces are available, not only in declining areas but also in growth centres in certain building types (such as offices) is not just illogical but also harmful from the resource efficiency perspective. Were policy-makers and planners aware of the youngness of demolished buildings' age distributions and the extent of vacancy in Finland, they could instead choose to work towards encouraging buildings' continued use and adaptive reuse. The findings of the current study imply, for instance, that the need to increase floor area may result in demolition decisions. This increase could, however, also be achieved through building extensions and/or infill development, if policies did not exacerbate demolition, as Thomsen, Schultmann and Kohler (2011) have argued. Moreover, the shorter lives of NRB and their replacement with RB suggest that adaptive reuse as RB could be a viable option for extending the lives of NRB. This strategy has also been proposed by Bradley and Kohler (2007), who have reasoned that NRB are not structurally inferior to RB. These prospects could enlarge business opportunities for construction enterprises specializing in renovation of existing buildings.

Besides construction companies, also building owners could be expected to be interested in insights that the current research offers for the development of buildings. These kinds of practical implications of the dissertation are mostly related to the exemplary cohort that was investigated in more detail. Even prior to this research, there were many studies regarding the renovation of the examined cohort that relied on 'typical' buildings or flats, although the selection of these acclaimedly representative units was based on intuition rather than research. The results on the spatial qualities of the studied cohort do not only provide a basis for developing mass-customizable renovation and home modification concepts but also validate the choices made in prior similar studies and increase their usefulness retroactively.

The obsolete parts of building stocks withhold significant potential, not only in the physical sense but also in terms of business. If these buildings continue to be ignored, chances are that not only their resources but also these opportunities will be wasted. So far, the rate of demolition has been moderate in Finland. Given the extents of vacancy and underutilization, however, an unforeseeable number of these buildings might face demolition in future, creating either unprecedented amounts of demolition waste or a major input of materials and components into the construction industry. Therefore, the business opportunities in the demolition, deconstruction, recycling and reuse of the materials from the existing stock should be acknowledged better.

4.2 Reliability and validity

4.2.1 Reliability

The reliability of a study is, in general, related to the capability of the findings to be repeated. In quantitative research, which this dissertation mostly represents, the reliability of a study is related to the accuracy of the results, *i.e.* the amount of random error. This accuracy is influenced by the sample itself, its processing and finally, the interpretation of the findings. Firstly, the sample needs to be large enough and representative (not skewed). Secondly, errors should be avoided in the collection and processing the data. Thirdly, the mastery of the method is necessary in order to land in correct conclusions from the data. (Heikkilä, 2004: 30, 187).

With regard to the reliability of the current dissertation, focal factors are the quality of the data and the assumptions made during its collection and processing. The data of Articles I and II leave no room for questioning the sample size, since the samples are, in fact, entire populations in a given time frame. The sample size in Articles III and IV, then again, can be considered sufficiently large, and the data can be deemed representative of the studied cohort. As discussed in detail in the articles themselves, statistical comparisons with several other data sources indicate that the collected data represents the entire cohort well. This view is further backed up by the repetitive nature of the findings, which indicated saturation of the data, *i.e.* a state in which 'no new or relevant data seem to emerge regarding a category' (Strauss & Corbin, 1990: 188), early on. This is despite the fact that the data was not picked completely randomly with regard to the geographical location of the buildings due to limitations set by the funding programme, which encompassed certain cities and towns. The collected data, nevertheless, has the vastest geographical coverage and sample size amongst similar studies so far. All in all, it is unlikely that any researcher would not land in similar findings about the flat types and panel dimensions even using a different sample.

When it comes to possible errors during the collection and processing of the data, *i.e.* the quality of the data, the aforementioned data sets are also to be looked at separately. The data of Articles I and II was pre-existing, part of the official PIS and BDR, and not collected by the author. Thus, the author could not have influenced its quality during the collection. As discussed in detail in Articles I and II, these are official data, which real estate taxation and right to use public services are based on. Therefore, the building owners as well as residents have strong financial incentives to keep the registry up-to-date, and there is no reason to believe that significant numbers of notable buildings would be missing from the data, or that permanently occupied flats would not be recorded as such in great numbers. Thus, the data can be considered highly reliable for the purposes of the current study. Compensation for missing area data was performed by the author especially for the data of Article I, in which it encompassed 14% of the buildings. In principle, this represents a possible source of error, but the basic procedure of the compensation has been described in the article, allowing it to be repeated and validated in future studies. In Article II, then again, the need for compensating missing figures was negligible (1% of buildings).

As for the data of Articles III and IV, the collection was designed, organized and supervised but not conducted by the author. Research assistants collected the data from the archives by the means of photography. Both the source of the data and the collection method are possible causes of inaccuracy. Firstly, the archives of ARA were chosen due to its geographical coverage and accessibility, even though the archived drawings are not building permit drawings. The possibility that the drawings would have significantly changed since applying the funding from ARA seems, however, negligible, because the turnaround time was minimized during the studied era. Secondly, photography was chosen as a method to reproduce the drawings because it enabled collecting a large sample in an affordable and relatively quick way. As a result, the documented drawings were not in scale. However, as the drawings contained standardized measures (such as the width of a door or the depth of a kitchen cabinet) and most of them even had gauge lines, they could easily be stretched to scale in a

CAD program. In some cases, the photography had skewed the largest drawings from the edges, or the taken photos were not completely focused but slightly blurred. The skewedness could be corrected in the program, and the blurriness did not prevent the measurements of the dimensions. With regard to the data processing of Article IV, it is also possible that errors would have occurred while the measured dimensions were inserted to a data table, because the work was highly repetitive. Therefore, they were checked by a research assistant other than who recorded them. The possibility of this kind of error was absent in Article IV, because the method of recording was different (graphic) and the exact dimensions were not decisive for defining the flat types, even though average representations of the types were also created.

Lastly, the researcher's capability to draw correct conclusions from the findings is to be questioned. Since the main methods consisted primarily of simple statistical description, there are not many opportunities for errors that would arise from misunderstanding the limits of the method. When it comes to statistical correlations employed in Articles I and II, however, it should be noted, as always, that correlation does not equal causation, and no such conclusions have been drawn. In all, there is a reason to believe that all the findings of the research are repeatable, and thus, reliable.

4.2.2 Validity

In a valid study, the research design corresponds to the aims of the research. The research questions and indicators need to be set right with regard to the research objects. (Heikkilä, 2004: 29, 186). The aims set by the theoretical framework of the study, *i.e.* building stock research, which pursues to depart from case studies and to produce generalizable findings, guided the research towards an extensive approach and quantitative data and methods. The selection of data sources and the acquisition of the data were designed with quantitative methods in mind. With regard to the research objects of Article IV, *i.e.* recognizing repetitive flat plan designs, a purely numerical approach would not have corresponded to the aims. Therefore, a mix of statistical description and graph theory informed typological approach was employed.

In quantitative research, validity is especially related to avoiding systematic errors, which resonates with a clear understanding of the studied population and the size and representativeness of the sample. (Heikkilä, 2004: 29, 186). The lastly mentioned matters have already been discussed in the previous chapter. However, if the data of Articles I and II, which represent entire populations in a given time, are instead understood as samples in a temporal sense, a just question is in which populations can the results, then, be generalized. This is the basic question with regard to external validity (Metsämuuronen, 2003: 35). Since the interests of the study lie rather in the future than in the past, the more specific dilemma is, thus, for how long the acquired findings describe demolition and vacancy in a valid manner. Because the findings indicate that the mortality of Finnish buildings is dynamic, *i.e.* changes in time, this is a highly relevant question. However, as it has been suggested that the world would soon be shifting from one economic supercycle to another, characterized, above all, by resource intelligence forced out by resource scarcity (Wilenius & Kurki, 2012: 88), the most meaningful question might, thus, not be, when the findings stop being valid, but how they can contribute to this shift.

To discuss the validity in a more conventional sense, the possibility of systematic errors in the study arises from the same factors that influence the study's reliability: the quality of the data and the choices made during the research. With regard to the data of Article I, the question is whether the data systematically omits parts of the building stock. The only group that could plausibly be omitted is that of minor cold utility buildings. Many of them escape registration in the BDR because their construction does not often require applying a permit or delivering a notification to the authorities. The skewedness of data resulting from this is, however, insignificant given the extent and characteristics of the entire building stock and the purposes of the current study.

When it comes Article II, the possibility of a systematic error is not so much related to the data itself. This is because the data encompasses residential buildings only, and they should be reliably registered due to their size and significance. In theory, the BDR could encompass some inhabitable buildings, but because the owners pay taxes based on the registered buildings, they have a strong incentive to have such buildings removed from the registry. However, the borderline between normal and problematic extents of vacancy, which had to be set by the author, is a possible source of systematic error. Its selection was based on an extensive literature review, which was practically the only way for setting it in the face of a lack of pre-existing definitions. The borderline was considered to be set at the 'safe' side, rather undermining the extent of problematic vacancy than exaggerating it. One problem in this was the different sizes of multi-family buildings. To retain the simplicity of the investigation, only one definition was given for the problematic vacancy of multi-family buildings, although different indicators could have been considered for buildings with different numbers of homes. The fact that uses as temporary or second homes are not included in the data also influences the possibility of a systematic error arising from these definitions, since some of the homes considered empty might factually be in a kind of use. However, because the underlying motive of the research is related to ecological sustainability and such uses tend to be irregular and thus, inefficient with regard to energy or resource use, their omission is not decisive.

With regard to Articles III and IV, the possibility of systematic errors seems highly unlikely. The geographical coverage and the size of the sample are large enough not to include omissions that could systematically distort the findings. Neither seems there to be anything in the processing method that could contribute to such an error. Rather, the possible errors stemming from it are random mistakes. Moreover, the findings of all the articles are more or less in line with the existing theory basis, which they help to sharpen and expand. This is usually considered as a sign of validity (Anttila, 2006: 512).

5 Conclusion

Basing on the paradigm of building stock research, this dissertation has explored the composition and relations of the obsolete parts of the Finnish building stock and refined the results by zooming into an exemplary cohort, whose composition was investigated in more detail in order to quantify the reserves of spaces and components in existing, problematically vacant as well as demolished buildings of the cohort.

The examination showed that with the help of the Finnish BDR data, the reserves of demolished and vacant buildings can be localized and characterized in terms of the involved building types, their decades of origin as well as the construction materials. The reserves of vacant buildings are manifold in comparison to annual demolition as well as new construction. Whereas vacancy rates may be higher in rural areas, geographically concentrated, significant reserves of both vacant and demolished buildings situate in cities. NRB, which are larger, younger and more often made out of concrete than RB, dominate the demolitions. Their vacancies could not be investigated with the available data, but the basic mechanisms leading into their vacancy are assumed to be similar to those of RB.

Moreover, the inquiries into the relations between demolition, vacancy, new construction, existing stock and population were able to amplify existing knowledge about the dynamics of the stock, currently largely relying on theorizing. Although no explicit relationship between demolition and vacancy was identified, the key finding from reserve point of view is the ‘economy of scale’ effect. This is to say that the absolute volumes of demolition and vacancy follow the sizes of population and the building stock. The relative values, such as vacancy rates, may be highly relevant from local governance and urban planning perspectives, but the absolute amounts are more decisive in terms of national resource policies.

Aiming at the highest steps of the European waste hierarchy, the research also showed how an age-use cohort (in this case, the 1960s–80s blocks of flats) can be inventoried in terms of its spatial arrangements and component composition, allowing the quantification of such resources in the entire stock and the assessment of their adaptation and modification potential. The layouts of the cohort's homes were found to adhere to 10 basic flat types covering 80% of the cohort, and the panels of the cohort's buildings were shown to comply with present-day norms for dimensioning living spaces in low-rise housing.

Lastly, the dissertation quantified the demolished and vacant parts of the building and housing stocks by proportioning them to ongoing new construction. New construction was observed to exceed demolition in practically all building types and municipalities, offering, thus, a viable sink for the material resources of the condemned buildings. The reserve in the problematically vacant part (*i.e.* detached houses without permanent residents for more than two years and multi-family housing with more than 10% of homes without permanent residents for more than six months) was found particularly large, equalling to the construction needs of more than a decade, or even several decades, in half of all communities. The size of the reserve is, in fact, so significant that were it condemned, it would take more than a century to demolish it at the current pace. Furthermore, the results of the exemplary cohort's spatial and component composition allowed quantifying the flat types and the amounts of panels or panel surfaces in the existing, underutilized and demolished parts of the cohort.

Although only the reserves and not their environmental effects were quantified, by highlighting the magnitudes of these reserves the research implies that public policy should start paying more attention to secondary resources. Due to their significant sizes, the problematically vacant parts of stocks may produce unprecedented amounts of these materials in future, were they condemned. Given the short average lifespans of demolished buildings, the sustainability of such practices is highly questionable.

5.1 Recommendations for further research

Due to the extent of the building stock and the complexity of the phenomena involved, one dissertation is but a scratch on the surface. In all, research on the building stock in Finland, regardless of the more specific topics, should adopt the new paradigm of building stock research, characterized above all by a top-down interest and the production of generalizable findings. Despite the good state of data in international comparison, there are aspects to the Finnish stock where knowledge and data are clearly lacking. Shifting from the performance of buildings to their potential also requires novel approaches.

Although research on renovation is vigorous, the issue has not been addressed from a stock-centred perspective. This denotes that there is a lack of the big picture. Statistics focus on the monetary value of repair activities in RB. Commercial and office buildings and certain public buildings were added to these statistics as late as in 2013 and 2014, in a respective order (OSF, 2013; 2014), but apart for them, little is known about the prevalence and extent of repairs in NRB. Moreover, the need for technical repair is important, but the adaptability to changed and new uses is even more decisive. Thus, there is a need to understand the characteristics of different age-use cohorts better.

While this study extended the knowledge regarding blocks of flats from a selected era, there are numerous other age-use cohorts whose plans and structures, and the prevalence of those, remain unknown. In the group of RB, these include blocks of flats from other decade as well as detached houses, largely neglected so far even though the value of their renovation activities surpasses that of blocks of flats (OSF, 2014). In NRB, significant groups would be the ones emphasized amongst demolished buildings, *i.e.* industrial, warehouse, commercial, office and public buildings. As suggested by Kohler, Steadman and Hassler (2009), GIS could act as a medium in which the existing BDR data would be brought together with the accumulating cohort data, allowing top-down data to be combined with bottom-up findings.

When it comes to the dynamics of the stock, the understanding on demolition should be extended with longitudinal research. Reconstructing all-time historical (pre-BRD, *i.e.* pre-1980) data on the building stock would allow modelling the real survival ages of buildings in different age-use cohorts, which are decisive for the life cycle environmental impacts of buildings. Methodology for this kind of analyses has been provided by Johnstone (1993), Bradley and Kohler (2007), and Aksözen, Hassler and Kohler (2016).

If data on the material content of buildings existed on the unit level, the current data would enable the quantification of the building stock, in particular the problematically vacant residential part, as the future’s material deposit and allow the comparison with geogenic reserves. Moreover, if information about the cohorts’ component composition existed more widely, this data could also be combined with demolition data in metabolism modelling, thus quantifying component flows instead of mere materials. LCA could support the actuation of these reserves by demonstrating how much carbon emissions could be yielded were the secondary reserves employed at the highest levels of the waste hierarchy. As a significant part of the vacancies investigated may, in fact, result from voluntarily multi-locational lifestyles, the environmental impacts from the energy used for heating largely vacant and underutilized buildings, such as vacant homes and holiday homes, should also be quantified. Collecting data on the vacancy of NRB is another challenge that needs to be overcome in order to create a full picture about the environmental impacts of the underutilized parts of the building stock.

One more aspect that this study has not covered, but that would deserve more research attention, is the adaptive reuse of buildings. Studying existing conversions *en masse* is an opportunity to probe the potentials building types have for other uses.

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Appendixes

Appendix I: Building classification 1994

Main class	Subclass	Building type
Residential buildings	Detached and semi-detached houses	One dwelling houses
		Two-dwelling houses
		Other detached and semi-detached houses
	Attached houses	Row houses
		Terraced houses
	Blocks of flats	Balcony-access blocks
		Other blocks of flats
Free-time residential buildings	Free-time residential buildings	Free-time residential buildings
Commercial buildings	Wholesale and retail trade buildings	Shopping halls
		Shops, department stores and shopping centres
		Other wholesale and retail buildings
	Hotel buildings	Hotels etc.
		Holiday, rest and recreation homes
		Rental holiday cottages and flats
		Other hotel buildings
	Residential buildings for communities	Residences for communities etc.
		Other residential buildings for communities
	Restaurants and other similar buildings	Restaurants and other similar buildings
Office buildings	Office buildings	Office buildings
Transport and communications buildings	Transport and communications buildings	Rail and bus stations, air and harbour terminals
		Vehicle depots and service buildings
		Car parks
		Communications buildings
		Other transport and communications buildings

Buildings for institutional care	Health care buildings	General hospitals
		Other hospitals
		Health centres
		Specialized health care buildings
		Other health care buildings
	Social welfare buildings	Old-age homes
		Children's homes, reform schools
		Nursing homes for the mentally retarded
		Other social welfare buildings
	Other social service buildings	Children's day care centres
		Social service buildings n.e.c.
	Prisons	Prisons
Assembly buildings	Theatres and concert halls	Theatres, opera houses, concert halls and congress centres
		Cinema halls
	Libraries, museums and exhibition halls	Libraries and archives
		Museums and art galleries
		Exhibition halls
	Association and club buildings etc.	Association and club buildings etc.
	Buildings of religious communities	Churches, chapels, monasteries, convents and prayer houses
		Parish halls
		Other buildings of religious communities
	Buildings for sports and physical exercise	Indoor ice rinks
		Indoor swimming pools
		Indoor tennis, squash and badminton courts
		Gymnasia and other sports halls
		Other buildings for sports and physical exercise
	Other assembly buildings	Other assembly buildings
Educational buildings	General education buildings	General education buildings
	Vocational education buildings	Vocational education buildings
	University and research institute buildings	University buildings
		Research institute buildings

	Other educational buildings	Educational buildings of organisations, unions, employers etc.
		Educational buildings n.e.c.
Industrial buildings	Buildings for energy supply etc.	Power stations
		Public utility buildings
	Industrial production buildings	Manufacturing plants
		Workshops for industry and small-scale industry
		Other industrial production buildings
Warehouses	Warehouses	Industrial warehouses
		Commercial warehouses
		Other warehouses
Firefighting and rescue service buildings	Firefighting and rescue service buildings	Fire stations
		Civil defence shelters
		Other firefighting and rescue service buildings
Agricultural buildings	Livestock buildings	Cowsheds, pig houses, hen-houses etc.
		Animal shelters, harness horse stables, manèges etc.
	Other agricultural buildings	Grain drying and storage buildings
		Greenhouses
		Fur farms
		Other buildings in agriculture, forestry and fishing
Other buildings	Other buildings	Sauna buildings
		Outbuildings
		Buildings n.e.c.

Source: Tilastokeskus, 1994

Appendix II: Classifications used in this study

Building Classification 1994	**This study[1] (normally)**	**This study[2] (Chapter 3.4.1)**
Detached and semi-detached houses	Detached houses	Detached houses
Attached houses	Row houses	Row houses
Blocks of flats	Blocks of flats	Blocks of flats
Free-time residential buildings	Holiday cottages	Holiday cottages
Residential buildings for communities	Dormitories	Commercial and office buildings
Commercial buildings without residential buildings for communities, office buildings	Commercial and office buildings	
Buildings for institutional care, assembly buildings, educational buildings, firefighting and rescue service buildings	Public buildings	Public buildings
Warehouses	Warehouses	Industrial and warehouse buildings
Industrial buildings	Industrial buildings	
Agricultural buildings	Agricultural buildings	Agricultural buildings
Transport and communications buildings	Transport buildings	Transport buildings
Buildings n.e.c.	Other buildings	(Not included)
Sauna buildings, outbuildings	Utility buildings	
(no class recorded)	Unknown buildings	

Notes:

1) Names of classes simplified in comparison to Building Classification 1994 and dormitories extracted to a category of their own from because they differ significantly from other commercial and office building types;

2) Classification simplified to allow comparison with statistics on the existing stock, utility and unknown buildings omitted because they are also omitted from the statistics.

Appendix III: Building attributes in the BDR

Field	**Specifications**
Building identification code	
Coordinate zone	
North coordinate	
East coordinate	
Precision of coordinates	
Map leaf	
Neighbourhood	
Voting area	
Other identification number	
Name of estate	
Parcel	yes / no
Construction date	
Existence of urban plan	detailed plan / shore plan / master plan / no plan
Tenure type	owned / rented
Main facade material	concrete / bricks / metal / stone / wood / glass / other
Floor area	
Number of floors	
Gross area	
Volume	
Basement area	
State of usage	permanent residence business premises holiday residence other temporary residence vacant demolished due to new construction demolished for other reasons destroyed abandoned due to decay unknown other
State of usage registration date	
Building type	(see Appendix I)
Heat distribution method	hot-water heating / warm-air heating / electric heating / fireplace / no heating
Heat source or fuel type	district heating / light fuel oil / heavy fuel oil / electricity / gas / coal / wood / peat / geothermal / other
Last building permit completion date	
Construction material	concrete / bricks / steel / wood / other
Construction method	prefabricated / in situ built
Electricity	yes / no / not known
Gas	yes / no / not known
Sewer	yes / no / not known

Water supply	yes / no / not known
Warm water	yes / no / not known
Solar panels	yes / no / not known
Elevator	yes / no / not known
Ventilation	yes / no / not known
Number of saunas	
Number of pools	
Capacity of bomb shelters	
Connection to sewer network	yes / no / not known
Connection to fresh water network	yes / no / not known
Connection to electric grid	yes / no / not known
Connection to gas network	yes / no / not known
Connection to cable television network	yes / no / not known
Reason for deviation permit	
Floor area, residential spaces	
Floor area, nursing spaces	
Floor area, assembly spaces	
Floor area, other spaces	
Floor area, shop spaces	
Floor area, educational spaces	
Floor area, office spaces	
Floor area, production spaces	
Floor area, warehouse spaces	
Renovation date	
Last registration date	
Number of homes	
Number of business premises	
Area of business premises	
Funding source, new construction	state-subsidized / municipality-subsidized / not subsidized or unknown
Funding source, renovation	state-subsidized / municipality-subsidized / not subsidized or unknown
Date of issue, new construction loan	
Date of issue, renovation loan	
State-subsidization of housing	state-subsidized rental housing / state-subsidized right of occupancy housing / previously but no longer subsidized / not known
Previous building identification code	

Source: Väestörekisterikeskus, 2011

Appendix IV: Home attributes in the BDR

Field	Specifications
Building identification code	
Letter of staircase unit	
Number of flat	
Letter of flat	
Address number	connects the home to an address in another file
Number of rooms	
Kitchen type	kitchen kitchenette kitchen-living room
Floor area	
WC	yes / no / not known
Shower / bath	yes / no / not known
Sauna	yes / no / not known
Balcony / terrace	yes / no / not known
Warm water	yes / no / not known
Tenure type	owner-occupied rental company housing right of occupancy other unknown
State of usage	permanent residence business premises holiday residence other temporary residence vacant demolished due to new construction demolished for other reasons destroyed abandoned due to decay unknown combined with another home or divided into many
State of usage registration date	

Source: Väestörekisterikeskus, 2011

ORIGINAL PAPERS

I

STATISTICAL AND GEOGRAPHICAL STUDY ON DEMOLISHED BUILDINGS

by

Huuhka, S. & Lahdensivu, J., Jan 2016

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Abstract

Demolition of buildings is one fundamental but little studied factor participating in the dynamics of building stocks. This paper applies an explorative research strategy and studies the characteristics and location of demolished buildings in Finland as well as motives behind the demolition decisions. A statistical and geographical analysis was performed on a data set of all 50 818 buildings demolished in Finland between 2000 and 2012. The study shows that in the Finnish context, the amount of demolition, the size of the community, demographic development and construction activity are all interconnected. In general, the larger the community, the more it gains inhabitants and the more is built as well as demolished. The data confirms that removals from the building stock are a result of conscious deliberation; sudden destruction and gradual deterioration due to abandonment play minor roles. Non-residential buildings dominate the demolished floor area. In addition, they are much larger and younger at the time of demolition than residential buildings, which consist primarily of detached houses. Demolitions are geographically concentrated: cities covering little over 5% of Finland's area are accountable for 76% of demolished floor area; and city cores with the area of only 0,2% for as much as 44%.

1 Introduction

Demolition of buildings is one fundamental but little studied factor participating in the dynamics of building stocks. As buildings are not natural creatures, they do not die naturally: well-built and regularly maintained buildings could last virtually forever. Hence, the Waste Framework Directive that EU launched in 2008 prioritizes adaptive reuse of buildings and reuse as components over recycling as material and other utilization from the material efficiency viewpoint (EU, 2008, p. 10). Obsolete parts of building stocks can be considered as reserves for present and future needs (Kohler & Hassler, 2002) and their value should not be evaluated solely based on current performance but also their potential for adaptation (Thomsen & van der Flier, 2011). Sustainable management of these stocks has been said to require preservation of natural and cultural capital embedded in them (Kohler, Steadman & Hassler, 2009).

Preservation has traditionally been the field for architectural conservationists. Consequently, the work has focused on historical, cultural and architectural values of monuments. Less weight has been given to the contemporary building stock, because it is usually not assessed valuable with traditional conservational criteria. Urban planners have a central role in providing opportunities for adaptive reuse, as planning affects building owners' possibility to develop existing properties. Yet, preserving embedded resources has received very little attention in urban planning. However, the interest in energy efficient and low-carbon planning has been growing. This trend may result in initiatives favouring demolition, because policies can often create regimes that promote demolition over other alternatives (Thomsen et al., 2011).

The more important it is to recognize that demolition — as a choice instead of life cycle extension — may also be linked to global warming, because manufacture of new construction materials is a significant source of greenhouse gas emissions. The production of cement, for example, was responsible for 5% of global greenhouse gas emissions in 2005, which equalled half the share of emissions from the usage of all existing residential buildings (Herzog, 2009). Accordingly, some authors have paid attention to the growing significance of construction phase emissions (Dutil, Rousse & Quesada, 2011; Fuller & Crawford, 2011; Heinonen, Säynäjoki & Junnila, 2011; Heinonen, Säynäjoki, Kuronen & Junnila, 2012; Kallaos, 2010), while others have noticed a bias in temporal allocation and discounting of such emissions in life-cycle assessment (LCA) (as summarized in Kallaos, 2010). In short, LCA usually assumes a linear payoff of the construction-phase emissions during an estimated service life even though these emissions are factually released to the atmosphere when the building is built (Heinonen et al., 2011 & 2012).

Although researchers generally accept that use-phase emissions do eventually exceed those of the production phase, earlier LCA methodology might have favoured new construction in a biased manner due to this shortcoming in temporal allocation. Those authors who have explicitly compared new construction with life cycle extension using different methods have concluded in favour of the latter (Heinonen et al, 2011; Itard & Klunder, 2007; Power, 2008 & 2010; Thomsen & van der Flier, 2009). While these papers mainly focus on ecological sustainability, attention has also been paid to social (un)sustainability of demolition (e.g. Kohler & Hassler, 2002; Gilbert, 2009; Power, 2008 & 2010). Hence, Kohler et al. (2009, p. 453) have reminded that:

> *'The shortcomings of combining directly building-centred energy-saving strategies with demolition programmes, without taking into account intangible criteria of building quality and value or socio-economic consequences, are very evident.'*

Building stocks can also be considered as future reserves for construction materials, which Thomsen et al. (2011) refer to as 'urban mining'. Similarly as life-cycle extension, reuse of building components has not only been found to conserve resources but also to contribute to climate change mitigation. For example, reusing a prefabricated concrete panel has been calculated to reduce–global warming potential by 98% compared to using a new panel (Asam, 2006). Reuse can also be a much better option than recycling, as the carbon footprint of recycled aggregate concrete is, in fact, worse than with virgin aggregates (Asam, 2007). Likewise, reuse of steel and timber structures has been found to possess notable energy saving potential, especially if they were designed for deconstruction (Densley Tingley, 2013, pp. 112–155 & 163; Pongiglione & Calderini, 2014). However, reuse does not have a significant position in the EU yet because of high labour costs (Hiete, Stengel, Ludwig & Schultmann, 2011).

If adaptive reuse and component reuse are to be promoted as literature and Waste Framework Directive encourage, there is a need to understand demolition patterns, drivers behind demolition and properties of demolished buildings better. Although several authors have recognized this demand, acquiring research material on demolished parts of stocks has proved difficult (Kohler & Hassler, 2002; Kohler et al., 2009; Thomsen, Schultmann & Kohler, 2011). Having studied demolition in the Netherlands and other European countries, Thomsen and van der Flier (2011) state that neither demolition of non-residential property nor demolition motives of private proprietors are normally included in statistics or other data. In Bradley and Kohler (2007), demolition data was collected from one German town to enable testing a dynamic building stock model. As far as the authors know, no studies are available in English that would have been conducted on demolished buildings with extensive data; the existing knowledge is based on mathematical models and small samples. However, in the case of Finland, appropriate data is a part of the official Building and Dwelling Register.

The purpose of this paper is to study properties and location of demolished buildings in Finland as well as the motives behind demolition decisions. The hypotheses are that demolition is related to 1) demographic change (which is related to structural changes in production and regional economics); 2) new construction; 3) type and size of settlement, 4) type of building; and that 5) demolition is not related to age of buildings straightforwardly. Table 1 presents the research questions.

Theme	Question(s)	Motivation for question(s)
Geography	How is demolition located geographically and with regard to growing and shrinking communities or urban and rural areas?	Location of material or parts possibly retrievable for recycling and reuse with regard to ongoing construction activity in the area.
Motives	What are the motives for decommissioning buildings?	Understanding what kind of obsolescence (physical or behavioural) demolition decisions are tied to. Possibility to avoid demolition, quality of decommissioned building parts.
Materials	What construction materials are prevailing in demolished buildings? What percentage of demolished buildings is built with prefabrication technology?	Reworkability of used building materials, recycling and reuse potential. Preconditions for reuse of components instead of recycling as material.
Building types	What building types are prevailing? What buildings replace demolished stock?	Structure types, recycling and reuse potential with regard to replacing construction activity.

Table 1. Research questions, themes and motivations

2 Background

2.1 Empirical and theoretical knowledge on demolition behaviour

In Western Europe, demolition rates generally vary between 0,05% and 0,10% (Thomsen & van der Flier, 2011). Thomsen and van der Flier (2011) have observed that obsolescence often leads to demolition. Their fourfold conceptual model for obsolescence distinguishes between endogenous and exogenous as well as physical and behavioural factors (Thomsen & van der Flier, 2011). Characteristic situations have been recognized for large-scale demolitions: fast growth, intensive transformation and shrinkage following demographic decrease or deindustrialization (Thomsen et al., 2011). As for fast growth, studies have observed that most demolition has taken place in tight markets in the Netherlands (Thomsen, 2009) and Finland (Huuhka, 2013). As for shrinkage, population decline has led to the demolition of mass housing sometimes not older than 20 years of age in Eastern Germany (Deilmann, Effenberger & Banse, 2009). In Finland, building stocks and built-up areas have been found growing in shrinking settlements (Huuhka, 2013), which can be explained with the 'shrinkage sprawl' phenomenon observed elsewhere as well (Siedentop & Fina, 2010; Mallach, 2011; Reckien & Martinez-Fernandez, 2011). As Thomsen and van der Flier (2011) put it, vacant buildings on valueless land will not become demolished. When it comes to 'intensive transformation', contemporary examples include large-scale demolitions of mass housing in France, Britain, the Netherlands and US (Thomsen et al., 2011). These wipeouts have represented policies against social problems (e.g. Gilbert, 2009; Kohler et al., 2009; Power 2010; Mallach, 2011). Kohler and Hassler (2002) call this 'social obsolescence' and Mallach (2011) 'problem-driven demolition'.

As for the significance of buildings' physical attributes, Kohler and Hassler (2002) state that demolition reasons do not correlate with age of buildings. They associate demolition with functional and formal obsolescence (i.e. quality-driven demolition as in Thomsen & van der Flier, 2009, or product-driven demolition as in Mallach, 2011) and land value (or profit-driven demolition as in Thomsen & van der Flier, 2009). Van der Flier and Thomsen (2006, as quoted in Thomsen & van der Flier, 2009) found the same in the Netherlands: although the older the building, the higher the chance for demolition, the relation was not linear and excluded large-scale demolitions of post-war housing. These buildings did not represent the worst part of the stock from the physical point of view; landlords merely preferred to justify demolition decisions with bad condition, although the real reasons were connected to social problems or unsatisfactory profitability (Thomsen & van der Flier, 2011). Schwaiger et al. (2000, as quoted in Kohler & Hassler, 2002) have also observed that demolition has typically resulted from productional or administrative reasons, not condition or age; in addition, large and flexible buildings survive longer than small and single-use buildings (Kohler & Hassler, 2002). In Ettingen, Germany, Bradley and Kohler (2007) documented a tenfold demolition rate for non-residential buildings (NRB) compared to residential buildings (RB), but did not believe that discrepancy in structural robustness could explain this difference. Thomsen and van der Flier (2009 & 2011) have also distinguished between the stability of residential functions and the short-livedness of non-residential functions as well as the significance of tenure (rented vs. owned). To sum up, although physical attributes such as structure, form, location and function have been enlisted to influence the survival of buildings (Thomsen et al., 2011), behavioural factors such as economics, lifestyle and tenure are nowadays considered as decisive (Thomsen et van der Flier, 2011).

2.2 Mechanics in dynamic building stock models

Building stocks have also been simulated with dynamic models, which take into account inflows and outflows. Some of these models, e.g. Müller (2006); Bergsdal, Brattebø, Bohne and Müller (2007); Sartori, Bergsdal, Müller & Brattebø (2008) and Hu, Bergsdal, van der Voet, Huppes and Müller (2010), assume correlations between population growth, new construction and demolition, although the empirical evidence has been sparse. Material flow analyses have been conducted for dwelling stocks in some countries using these models. The analyses require accurate statistics on materials used in buildings of different ages and types ('vintage cohorts'), which are very seldom available reliably. The models assume and apply normal distribution for lifetime and demolition profiles of dwellings (Müller, 2006; Sartori et al., 2008), because there is lack of data on real lifetimes and demolition times. However, Bekker (1978) has concluded in the favour of the Weibull distribution for the demolition of buildings. Based on Lahdensivu (2012), the durability properties of existing concrete facades and balconies in Finnish dwellings are rather poor, which is why it could be assumed that the probability for renovation after quite a short service life would be higher in Finland than presented in Sartori et al. (2008). In addition, Sartori et al. (2008) discovered that modelling non-residential building stock would require a different approach than modelling the residential stock. Bradley and Kohler (2007) employ the Weibull fit in their model that focuses on how demolition behaviour is dependent on age and function of buildings. Unlike the previously mentioned models, Bradley and Kohler's (2007) model includes both RB and NRB. The model suggests a more intense turnover for younger buildings and NRB than for older buildings and RB (Bradley & Kohler, 2007). Similarly, Hassler and Kohler (2004, as quoted in Hassler, 2009) state that the younger the building, the lower the statistical probability for survival.

2.3 Structure of Finnish municipalities and building stock

Finland has nearly 5,5 million inhabitants in 320 municipalities. Most municipalities are small in the number of residents, the average being 17 000 inhabitants. The extremities are the capital Helsinki with 610 000 inhabitants and the municipality of Sottunga with 100 residents. The ten largest cities alone cover nearly 40% of the population. (Statistics Finland, 2014). As for the demographic development, for the last 20 years large cities have kept enlarging while small rural settlements have continued to decline. This re-concentration has followed an era of more balanced development from mid-1970s to early 1990s during which small communities were on the gaining side. (Aro, 2007). The building stock consists of two million buildings, the most of which are quite young. Only 4–5% of the stock was built before 1920 (Statistics Finland 2014), which places the Finnish housing stock among the youngest in Europe (Hassler, 2009).

Wood has dominated the construction of load-bearing structures, roofs and facades of detached houses and row houses at all times. In all, the share of wood facades is 34% (Vainio et al., 2005, p. 10). Masonry load-bearing structures came into use in blocks of flats, office and commercial buildings as well as industrial buildings during the 18th century and dominated the said building types until the late 1950s. The facades were rendered or fair-faced brick walls without thermal insulation. The thickness of these solid brick walls is between 450mm and 600mm. Currently, the share of bricks is 26% of all facades (Vainio et al., 2005, p. 10). Floors in block of flats were typically made of timber until the 1910s when cast-in-place reinforced concrete took over. In industrial buildings, reinforced cast-in-place concrete started to dominate the construction of load-bearing frames in the beginning of 1910s. (Neuvonen, Mäkiö & Malinen, 2002, pp. 26–50).

During the 1950s, concrete load-bearing structures became dominant for block of flats, office and commercial buildings as well as industrial buildings. In most cases, facades were made of bricks. At first, concrete used in load-bearing structures was cast in place. The development of precast concrete elements started in the 1960s, and an open panl system was established in 1969 (BES, 1969). Precast concrete elements became the dominant construction material in Finland during the 1970s. Since mid-1960s, the facades of concrete buildings have also been made of precast concrete panels. Approximately 50% of Finnish apartment stock has been built between 1960 and 1979 (Statistics Finland, 2014), and precast concrete panel system has been the dominant construction method in those buildings. The panel system developed during the 1960s still dominates the construction of block of flats, office buildings and commercial buildings. Steel has become the prevailing structural material in industrial buildings and warehouses during the second half of the 20th century.

A special characteristic of the Finnish building stock is the summer cottage culture. As Finland urbanized from the 1950s on, the homesickness of first generation city dwellers led to an increased popularity of second homes in the countryside. In addition to vigorous new construction, many village abodes were left behind and became temporary residences. (Statistics Finland, 2007). By 2013, nearly half a million holiday homes were in existence, representing one fourth of the whole building stock (Statistics Finland, 2014).

3 Research materials and methods

The research relies on quantitative methods, namely a descriptive statistical examination and a simple geographical analysis. The primary research material for the study is a data set of buildings demolished between 2000 and 2012, purchased from the Population Register Centre of Finland. The centre maintains the national Population Information System, which contains basic information about residents and buildings in Finland. The subsystem entailing information about buildings is usually referred to as the Building and Dwelling Register (BDR).

The acquired data table contains all buildings that have been reported demolished or destroyed between 2000 and 2012, a total of 50 818 records (rows). Each record contains over 50 informative fields (columns), the ones relevant for this study are the intended purpose of the building, reason for demolition, date of construction, date of demolition, floor area, volume and construction material. The demolished buildings belong to 50 different building types. To simplify the investigation, the building types were combined into 15 groups shown in Table 2, and further into residential (RB) and non-residential buildings (NRB). Holiday cottages were considered to be residential buildings but dormitories were not. The ages of the demolished buildings were added to the data by subtracting the construction year from the demolition year. Coordinates of the buildings are also included, which enabled geocoding the records on a map in a GIS program such as the MapInfo Professional used in this study. 1289 records did not have coordinates, and they were geocoded to the geometric centre of the municipality.

Thus, the raw data consists of 50 818 map points containing the same information as the original data table. These data points were turned into statistics through SQL and geographical query functions of the program. In addition, the research material was supplemented with another data set from the BDR as well as with official and other government-maintained statistics of Finland. The former included the records for buildings that have been built or that have received a building permit on the plots of the demolished buildings. The latter data sources (Statistics Finland, 2014; Suomen ympäristökeskus, 2014) were studied for demographic change and simultaneous construction activity. Due to the classification used in statistics for new construction, the 15 building types had to be reworked into 10 in this examination: industrial buildings and warehouses were combined into one category, commercial buildings, offices and dormitories into another and utility buildings had to be completely omitted.

Geographical studies were performed for four different types of areal divisions: for municipalities; for the groups of growing, steady-state and shrinking municipalities; the groups of metropolitan, urban, semi-urban and rural municipalities; and finally, for urban and rural zones, the borders of which are independent from those of municipalities. Borders of 2013 provided by the National Land Survey of Finland were used for municipalities. Numbers of inhabitants in 2000 and 2012 were added to records of the municipalities from official statistics to create the zones of growing, steady-state and shrinking municipalities. The municipality was considered growing if the population change exceeded +2,5%, shrinking if it fell below -2,5% and steady-state if it was ±2,5% during the examination period (following "Asuntokannan kehittäminen", 2011, p. 10). The categories of urban, semi-urban and rural municipalities, then again, originate from Statistics Finland (2013). In addition, the four municipalities forming the capital region were distinguished from the category of urban municipalities into their own group. As municipalities usually consist of urban and rural areas, a division based on municipal borders is often considered too rough. Finnish Environment Institute provides a more detailed categorization into urban and rural areas that is not bound to municipal borders (Suomen ympäristökeskus, 2014).

3.1 Quality of the data

The Finnish BDR was created in 1980 by surveying the erstwhile owners of the buildings. Since then, municipal building inspection offices have been bound by law to provide the information for new buildings as well as update the information of existing buildings on such changes that have required an official permit or notification (e.g. demolition). Information added by professional building inspection can be considered highly reliable. When a building is demolished, a form about the removal of the building ('RK9 form') is supposed to be filled in and submitted to the municipal building supervision, which then records the demolition to the BDR. Submitting the form ends the owner’s obligation to pay real estate tax on the building. This economic benefit can be expected encourage owners to report all demolitions, thus, the coverage of the data can be considered highly reliable.

Because the properties of the demolished buildings studied in this paper are of a permanent nature and changing them requires acquiring permits, the quality of the data depends mainly on the quality of the information provided by the building owners back in 1980. As this is primarily very basic information about the building, the owners should have been able to provide it reliably. The most uncertain one of these parameters is the year of construction, and a lot of pre-industrial buildings with the exact building year unknown have been recorded to year 1920 (K. Kaivonen, personal communication, September 12, 2014). For some parameters, estimates were used to bridge gaps in the raw data. 14 percent of records did not contain the information for floor area, and missing figures were compensated by using the average of each building type, calculated from those records in the data that contained the information. The volume was recorded only for 22 percent of the buildings, and the missing volumes were estimated with the help of the floor area and average height calculated similarly as the missing floor area.

For some parameters, filling in the data gaps was not possible. Luckily, the data already covered many these parameters well. They include the construction date (known for 93% of the records or 94% of floor area) and the construction material of the load-bearing structure (recorded for 56% of the buildings or 81% of the floor area). However, there were building groups for which the share of absent information was remarkable. For example, the construction material was not known for 75% of floor area in holiday cottages, 73% in other buildings or 66% in utility buildings. Alas, the construction method of the load-bearing structure (built in-situ or prefabricated) was documented for the minority (15% of count or 25% of floor area) of records. As brick structures are always built in-situ and steel structures are prefabricated, these observations were simply added to the data. After this addition, the information was still recorded only for 17% of buildings and 35% of floor area. In addition, the data is quite vague on demolition motives. The four options provided by the demolition form are new construction, other reasons, destruction and abandonment because of decay. The former refer to deliberate removal while the latter are less intentional. Giving distorted information seems unlikely, because the reported reason for demolition does not bring about any consequences to the owner. For the majority of parameters, the sufficiency of evidence and the level of accuracy in the data can be considered satisfactory for the purposes of this study.

4 Results

4.1 Total amount of demolition

According to the data, a total of 50 818 buildings were demolished in Finland between years 2000 and 2012. These buildings made up more than 9 million square meters of floor area and over 40 million cubic meters of volume. The annual number of demolished buildings ranged from 3251 to 4508 and the amount of floor area from over 475 000 m^2 to little under 953 000 m^2.

The 50818 demolished buildings were located on 39 635 pieces of real estate, 81% of which (32 287) had one demolished building. However, these buildings accounted for only 52% (4 704 448 m^2) of the floor space. 14% of properties (5595) had two demolished buildings with 19% (1 685 161 m^2) of floor area in total, and 3% (1061) real estates had three buildings with 9% (836 892 m^2) of floor area. The remaining 2% of properties (692) with four or more buildings was accountable for 20% (1 773 699 m^2) of floor area. The largest number of demolished buildings on one piece of real estate during the 13 years of examination was 30.

Simultaneously, over 227 000 buildings were built in Finland. The number of demolished buildings equals 22% of the simultaneous new production. This percentage, which can be named the 'replacement rate', suggests that every fourth or fifth new building 'replaced' an old one. When it comes to square meters, the replacement rate is smaller, 12%, meaning that 'replacing' buildings are generally larger than the old ones. During the examination period, the demolition rate was in average 0,25% of the existing stock if measured as the number of buildings, or 0,15% if measured as floor area. The average demolition rate for RB was 0,15% and 0,65% for NRB.

4.2 Building types, floor area and volume

Table 2 shows that by number, the largest group was detached houses (16 319), followed by utility buildings (15 335) and holiday cottages (7460). Despite their great number, these buildings are small in size. Consequently, the order is different if measured by floor area: industrial buildings (1,7 million m^2) are followed by detached houses (1,4 million m^2) and public buildings (1,3 million m^2). Commercial or office buildings (1,2 million m^2) and warehouses (1,1 million m^2) are remarkable groups, too. Table 3 presents the volumes of RB and NRB in the data. The shares of RB and NRB are almost equal, but NRB dominate demolished floor area. Demolished NRB are in general much larger than RB.

Name of the group	**Number of buildings**	**Total floor area (m^2)**	**Average area/ building (m^2)**	**Total volume (m^3)**	**Average volume/ building (m^3)**
Detached houses	16 319	1 448 106	89	4 738 208	290
Row houses	371	147 611	398	468 995	1264
Blocks of flats	487	260 700	535	913 406	1876
Dormitories	235	82 148	350	256 686	1092
Holiday cottages	7 460	286 553	38	801 495	107
Utility buildings	15 335	681 205	44	2 159 597	141
Commercial and office buildings	2 198	1 161 341	528	4 715 448	2145
Public buildings	1 094	1 266 795	1158	3 860 263	3529
Warehouses	1 504	1 063 813	707	6 176 337	4107
Industrial buildings	1 358	1 715 788	1263	10 454 830	7699
Agricultural buildings	1 034	383 736	371	1 669 896	1615
Transport buildings	989	634 554	642	3 181 301	3217
Other buildings	1 986	135 629	68	442 742	223
Unknown buildings	448	105 519	236	404 652	903
Total	**50 818**	**9 000 200**	**177**	**39 579 309**	**779**

Table 2. Volumes of demolished buildings by building types

Name of the group	**Number of buildings**	**Total floor area (m^2)**	**Average area/ building (m^2)**	**Total volume (m^3)**	**Average volume/ building (m^3)**
Residential buildings (RB)	24 637	2 142 970	87	6 922 104	281
Non-residential buildings (NRB)	25 733	6 751 711	262	32 917 100	1279

Table 3. Volumes of residential and non-residential buildings

4.3 Geographical examination

In terms of the number of inhabitants, the majority of communities have been in transition during the examination period: 30% have grown, 60% have been shrunk and only 10% have remained stable. As Figure 1 shows, the group of growing communities host the majority of demolition. The average area of buildings demolished in growing municipalities is also on average 36% larger than in steady-state communities and 53% larger than in shrinking communities.

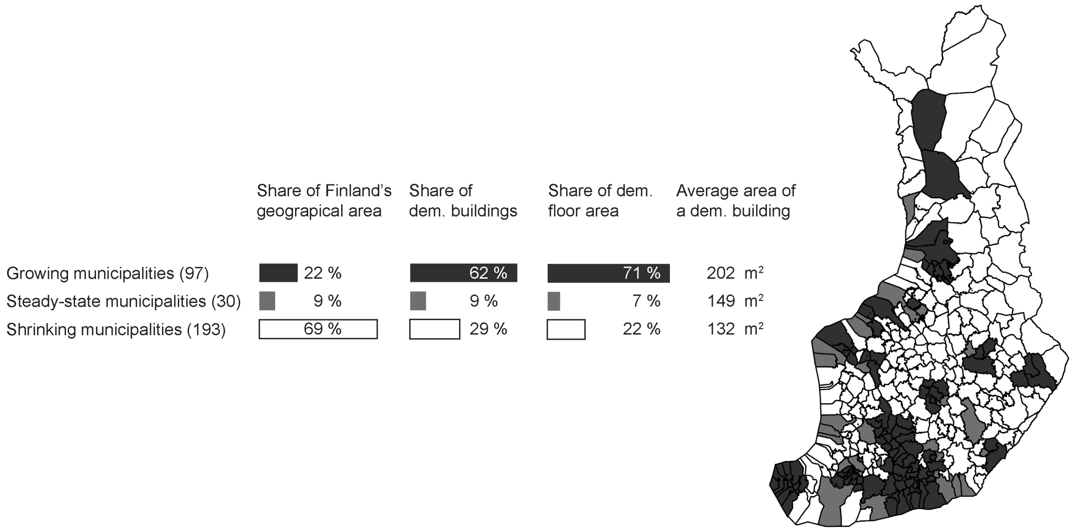

Figure 1. Shares of demolition in growing, shrinking and steady-state municipalities

Figure 2 shows that the capital region and urban municipalities are together accountable for most of demolition. In addition, the table demonstrates that the more urban the municipality, the larger the average area of the demolished buildings. As seen in Figure 3, the more urbanized the part of town, the more demolition takes place and the larger the demolished buildings are on average. In the cities, the average area is more than double than in the countryside. With this indicator, rural towns–are very close to cities.

Table 4 shows how different types of demolished buildings were located in these zones. For most building types, the majority of removals in absolute numbers took place in inner cities. Detached houses and utility buildings are remarkable in count for all the area types. As utility buildings stand for auxiliary buildings for residential houses, it can be assumed that their demolitions are often connected (when a plot is cleared).

	Share of Finland's geograpical area	Share of dem. buildings	Share of dem. floor area	Average area of a dem. building
Capital region (4)	0,4 %	20 %	26 %	228 m²
Other urban municipalities (53)	16,7 %	47 %	53 %	199 m²
[All urban municipalities (57)	17,1 %	67 %	79 %	207 m²]
Semi-urban municipalities (64)	21,5 %	15 %	11 %	134 m²
Rural municipalities (199)	61,4 %	18 %	10 %	99 m²

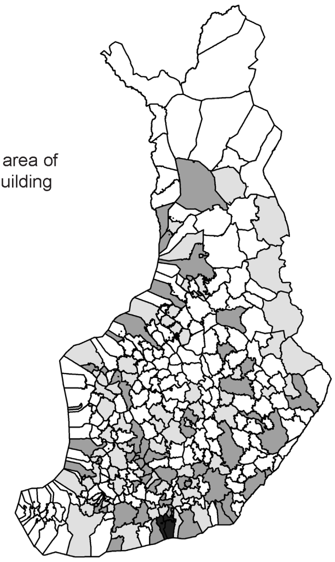

Figure 2. Shares of demolition in municipalities with different degree of urbanization

	Share of Finland's geograpical area	Share of dem. buildings	Share of dem. floor area	Average area of a dem. building	Dem. floor area per km²
Inner cities	0,2%	20%	44%	397 m²	5908 m²
Outer cities	0,6%	24%	22%	165 m²	935 m²
City rings	3,8%	16%	10%	104 m²	63 m²
Cities, total	**4,6%**	**60%**	**76%**	**224 m²**	**414 m²**
Rural towns	0,2%	4%	5%	226 m²	680 m²
Countryside near cities	11,1%	13%	6%	86 m²	14 m²
Cultivation countryside	15,3%	14%	8%	109 m²	14 m²
Sparsely populated countryside	68,8%	10%	5%	83 m²	2 m²
Countryside, total	**95,4%**	**40%**	**24%**	**107 m²**	**107 m²**

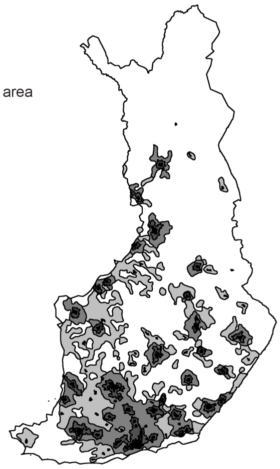

Figure 3. Shares of demolition in areas of different degree of urbanization

Detached houses are either number one or number two source of demolished floor area in all other area types except inner cities. In the countryside, detached houses, utility buildings and holiday cottages compose 82–88% of demolished buildings in number and 46–51% of floor area. Other types of residential buildings are clearly in the minority in number as well as floor area in all area types.

Name of the group **number (%)** **floor area (%)**	**Inner cities**	**Outer cities**	**City rings**	**Rural towns**	**Countryside near cities**	**Cultivation countryside**	**Sparsely populated countryside**
Detached houses	3 069 (31%) 329 581 (8%)	4 003 (33%) 341 711 (17%)	2 400 (29%) 199 937 (23%)	841 (42%) 79 033 (17%)	1 662 (26%) 138 128 (25%)	2 772 (40%) 234 479 (31%)	1 569 (31%) 125 028 (30%)
Row houses	82 (1%) 40 574 (1%)	66 (1%) 23 681 (1%)	36 (0%) 12 663 (1%)	34 (2%) 13 334 (3%)	46 (1%) 19 246 (4%)	64 (1%) 21 609 (3%)	38 (1%) 16 504 (4%)
Blocks of flats	243 (2%) 136 751 (3%)	87 (1%) 36 617 (2%)	27 (0%) 8 698 (1%)	48 (2%) 20 479 (4%)	32 (1%) 26 104 (5%)	33 (0%) 17 566 (2%)	17 (0%) 14 485 (3%)
Dormitories	50 (1%) 20 600 (1%)	50 (0%) 17 728 (1%)	47 (1%) 10 447 (1%)	21 (1%) 10 313 (2%)	27 (0%) 7 193 (1%)	18 (0%) 3 887 (1%)	22 (0%) 11 980 (3%)
Holiday cottages	125 (1%) 5 936 (0%)	752 (6%) 28 872 (1%)	1 636 (20%) 65 495 (8%)	79 (4%) 3 467 (1%)	1 891 (30%) 73 014 (13%)	1 361 (20%) 53 248 (7%)	1 613 (32%) 56 427 (13%)
Utility buildings	2 817 (28%) 150 313 (4%)	4 465 (37%) 185 372 (9%)	2 787 (33%) 100 234 (12%)	534 (26%) 84 570 (18%)	1 936 (30%) 66 226 (12%)	1 512 (22%) 58 255 (8%)	1 266 (25%) 35 208 (8%)
Commercial and office buildings	745 (7%) 706 970 (18%)	415 (3%) 202 430 (10%)	164 (2%) 46 649 (5%)	137 (7%) 56 720 (12%)	166 (3%) 36 993 (7%)	369 (5%) 71 531 (10%)	202 (4%) 40 048 (9%)
Public buildings	447 (4%) 475 427 (12%)	245 (2%) 169 307 (8%)	120 (1%) 84 265 (10%)	59 (3%) 56 815 (12%)	61 (1%) 26 430 (5%)	105 (2%) 53 699 (7%)	57 (1%) 27 554 (7%)
Warehouses	640 (6%) 593 738 (15%)	418 (3%) 285 378 (14%)	153 (2%) 70 796 (8%)	75 (4%) 35 703 (8%)	58 (1%) 25 576 (5%)	106 (2%) 40 726 (5%)	52 (1%) 11 366 (3%)
Industrial buildings	511 (5%) 948 245 (24%)	384 (3%) 453 741 (23%)	144 (2%) 119 460 (14%)	78 (4%) 57 723 (13%)	67 (1%) 36 055 (7%)	126 (2%) 67 612 (9%)	48 (1%) 32 952 (8%)
Agricultural buildings	91 (1%) 41 851 (1%)	185 (2%) 83 558 (4%)	218 (3%) 74 785 (9%)	8 (0%) 7 012 (2%)	209 (3%) 52 990 (10%)	235 (3%) 89 885 (12%)	86 (2%) 32 689 (8%)
Transport buildings	384 (4%) 413 963 (10%)	238 (2%) 110 853 (6%)	98 (1%) 28 829 (3%)	71 (4%) 27 267 (6%)	69 (1%) 20 640 (4%)	88 (1%) 22 535 (3%)	40 (1%) 10 455 (2%)
Other buildings	671 (7%) 61 582 (2%)	723 (6%) 33 292 (2%)	418 (5%) 23 294 (3%)	15 (1%) 2 212 (0%)	99 (2%) 10 036 (2%)	41 (1%) 4 047 (1%)	20 (0%) 1 207 (3%)
Unknown buildings	83 (1%) 33 120 (1%)	92 (1%) 22 651 (1%)	73 (1%) 17 240 (2%)	22 (1%) 4 043 (1%)	63 (1%) 10 641 (2%)	63 (1%) 11 109 (1%)	52 (1%) 6 715 (2%)
Total (100%)	9 963 (100%) 3 958 651 (100%)	12 123 (100%) 1 995 191 (100%)	8 321 (100%) 862 792 (100%)	2 022 (100%) 458 691 (100%)	6 386 (100%) 549 272 (100%)	6 893 (100%) 750 188 (100%)	5 082 (100%) 422 618 (100%)

Table 4. Volumes of demolition in communities with different zones of urbanization according to the building type

By floor area, industrial buildings were the largest group in both inner and outer cities and remarkable for city rings and rural towns as well. In inner cities, 69% of removed floor area originated from commercial and office, industrial, warehouse and public buildings: 12–24% each, although they all together account for only 22% of all buildings. The distribution to residential and non-residential floor area follows the degree of urbanization. In city cores, the share of residential floor area comprises as little as 12% of the totality, while in the most sparsely populated countryside, residential buildings made up half of total demolished floor area. Although the share of residential floor area is highest in the rurality, in absolute numbers most demolition takes place in the urbanity.

4.4 Building materials and construction methods

Tables 5 and 6 present the distribution of the construction material of the load-bearing structure in general as well as for different building types. While timber buildings form 87% of known records in number, timber (41%) and concrete (36%) together compose the majority (77%) of floor area for known records. Calculated average area demonstrates that demolished wooden buildings are usually small and concrete buildings large.

Construction material (load-bearing structures)	**Number**	**Percentage**	**Floor area**	**Percentage**	**Average area**
Concrete	1 654	3 %	2 636 590	29 %	1594
Bricks	1 120	2 %	857 543	10 %	766
Steel	1 024	2 %	580 764	6 %	567
Wood	24 460	48 %	3 007 490	33 %	123
Other	274	1 %	166 397	2 %	607
All known records	28 253	56 %	7 248 784	81 %	257
Unknown records	22 286	44 %	1 751 416	19 %	79

Table 5. Construction material of the load-bearing structure

Construction material (load-bearing structures) **number (%)** **floor area (%)**	**Concrete**	**Bricks**	**Steel**	**Wood**	**Other**	**Unknown**	**Total**
Detached houses	247 (2%) 34 670 (2%)	323 (2%) 52 146 (4%)	8 (0%) 478 (0%)	14 583 (89%) 1 256 251 (87%)	21 (0%) 2 004 (0%)	1 137 (7%) 102 557 (7%)	16 319 (100%) 1 448 106 (100%)
Row houses	37 (10%) 23 576 (16%)	36 (10%) 15 438 (10%)	2 (1%) 1 790 (1%)	285 (77%) 101 879 (69%)	1 (0%) 550 (0%)	10 (3%) 4 378 (3%)	371 (100%) 147 611 (100%)
Blocks of flats	95 (20%) 121 199 (46%)	40 (8%) 43 657 (17%)	0 (0%) 0 (0%)	344 (71%) 86 905 (33%)	1 (0%) 210 (0%)	7 (1%) 8 729 (3%)	487 (100%) 260 700 (100%)
Dormitories	20 (9%) 31 005 (38%)	8 (3%) 7 133 (9%)	8 (3%) 1 743 (2%)	166 (71%) 34 309 (42%)	4 (2%) 322 (0%)	29 (12%) 7 636 (9%)	235 (100%) 82 148 (100%)
Holiday cottages	12 (0%) 458 (0%)	4 (0%) 315 (0%)	1 (0%) 24 (0%)	1 641 (22%) 70 612 (25%)	7 (0%) 443 (0%)	5 795 (78%) 214 595 (75%)	7 460 (100%) 286 553 (100%)
Utility buildings	102 (1%) 80 017 (12%)	70 (0%) 11 429 (2%)	147 (1%) 10 227 (2%)	3 453 (23%) 127 301 (19%)	26 (0%) 907 (0%)	11 537 (75%) 451 324 (66%)	15 335 (100%) 681 205 (100%)
Commercial and office buildings	307 (14%) 605 255 (52%)	149 (7%) 123 072 (11%)	84 (4%) 28 319 (2%)	1 374 (63%) 310 352 (27%)	33 (2%) 9 322 (1%)	251 (11%) 85 021 (7%)	2 198 (100%) 1 161 341 (100%)
Public buildings	136 (12%) 280 994 (22%)	102 (9%) 178 744 (14%)	52 (5%) 36 593 (3%)	680 (62%) 284 640 (22%)	32 (3%) 53 509 (4%)	92 (8%) 59 017 (5%)	1 094 (100%) 1 266 795 (100%)
Warehouses	156 (10%) 353 960 (33%)	82 (5%) 63 225 (6%)	285 (19%) 188 560 (18%)	597 (40%) 248 617 (23%)	57 (4%) 38 779 (4%)	327 (22%) 170 672 (16%)	1 504 (100%) 1 063 813 (100%)
Industrial buildings	321 (24%) 764 864 (45%)	180 (13%) 287 297 (17%)	220 (16%) 187 120 (11%)	409 (30%) 270 358 (16%)	43 (3%) 35 444 (2%)	185 (14%) 170 705 (10%)	1 358 (100%) 1 715 788 (100%)
Agricultural buildings	45 (4%) 24 261 (6%)	25 (2%) 9 843 (3%)	91 (9%) 61 533 (16%)	383 (37%) 120 947 (32%)	14 (1%) 10 956 (3%)	476 (46%) 156 196 (41%)	1 034 (100%) 383 736 (100%)
Transport buildings	157 (16%) 293 201 (46%)	93 (9%) 49 991 (8%)	106 (11%) 60 689 (10%)	350 (35%) 73 827 (12%)	31 (3%) 13 448 (2%)	252 (25%) 143 398 (23%)	989 (100%) 634 554 (100%)
Other buildings	14 (1%) 15 847 (12%)	5 (0%) 3 261 (2%)	19 (1%) 3 511 (3%)	146 (7%) 12 827 (9%)	4 (0%) 503 (0%)	1 798 (91%) 99 680 (73%)	1 986 (100%) 135 629 (100%)
Unknown buildings	5 (1%) 7 283 (7%)	3 (1%) 11 992 (11%)	1 (0%) 177 (0%)	49 (11%) 8 665 (8%)	0 (0%) 0 (0%)	390 (87%) 77 402 (73%)	448 (100%) 105 519 (100%)

Table 6. Construction material by building type

Table 6 shows that wood was the dominating material by floor area for detached houses, row houses, holiday cottages, utility buildings as well as agricultural buildings. Concrete, on the other hand, prevails in the categories of blocks of flats, commercial and office buildings, warehouses, industrial buildings and transport buildings. Quite surprisingly, wood and concrete are almost even for public buildings. The information on the construction method of the load-bearing structure could be traced down for 8841 buildings (17%) or 3 168 015 m^2 of floor area (35%). Of these, 2107 (24%) were prefabricated with 1 073 340 m^2 (34%). Table 7 shows the figures by material.

Construction material (load-bearing structures)	**Number prefab.**	**Area prefab.**	**Number built in-situ**	**Area built in-situ**	**Number unknown**	**Area unknown**
Concrete	180	414 241	294	414 251	1 180	1 808 098
Bricks	0	0	1 120	857 543	0	0
Steel	1 024	580 764	0	0	0	0
Wood	1 188	220 302	4 904	608 319	18 368	2 178 869
Other	55	46 204	52	24 208	167	95 985
Material known	2 107	1 073 340	6 370	1 904 321	19 715	4 082 952
Material unknown	0	0	24	2 183	22 262	1 749 233

Table 7. Construction method (prefabricated / built in-situ / unknown) by material

4.5 Building year

Table 8 shows that demolition of floor area focuses on buildings built between the 1950s and the 1980s. For older groups up to 1950s, the share of buildings in count exceeds their share in floor area, which refers to a small average size of buildings, while decades from the 1950s to 1980s in many cases show the opposite. As a general rule, the oldest and the youngest buildings are in average smaller than buildings that date after the mid-20th century. As seen in Table 9, which elaborates on the building year by building type, either the 1960s or the 1970s is the most common construction decade for floor area in most building categories.

Building year	**Number**	**Percentage**	**Floor area**	**Percentage**	**Average area**
2000 -	920	2 %	199 911	2 %	217
1990 - 1999	2 300	5 %	457 547	5 %	199
1980 - 1989	4 575	10 %	1 184 868	14 %	259
1970 - 1979	7 964	17 %	1 811 503	21 %	227
1960 - 1969	5 925	12 %	1 722 380	20 %	291
1950 - 1959	8 525	18 %	1 189 769	14 %	140
1940 - 1949	6 054	13 %	735 271	9 %	121
1930 - 1939	3 669	8 %	421 460	5 %	115
1920 - 1929	5 581	12 %	586 864	7 %	105
1910 - 1919	588	1 %	60 154	1 %	102
1900 - 1909	745	2 %	74 837	1 %	100
- 1899	576	1 %	60 500	1 %	105
All known records	47 422	100 %	8 505 064	100 %	179

Table 8. Number and area of demolitions in different decades

In the earliest year groups, prior to 1960, detached houses clearly dominate the demolitions. In 1950s buildings, floor area from industrial buildings starts to remarkably gain on detached houses. Overall, floor area from industrial buildings is significant for decades from 1930 on: it is either the largest or the second largest category. Warehouses form another significant group from 1970 on. In addition, public buildings, commercial and office buildings as well as utility buildings show high numbers in demolished floor area in most decades.

Name of the group number (%) floor area (%)	-1899	1900-1909	1910-1919	1920- 1929	1930- 1939	1940- 1949	1950- 1959	1960-1969	1970-1979	1980-1989	1990- 1999	2000-	Total, known records
Detached houses	351 (2%) 32 088 (2%)	315 (2%) 27 610 (2%)	292 (2%) 26 376 (2%)	3 637 (23%) 275 324 (19%)	1 803 (11%) 138 640 (10%)	2 956 (19%) 248 432 (18%)	3 537 (22%) 315 038 (22%)	1 510 (9%) 162 639 (12%)	893 (6%) 103 969 (7%)	422 (3%) 53 352 (4%)	145 (1%) 20 025 (1%)	77 (0%) 10 428 (1%)	15 938 (100%) 1 413 921 (100%)
Row houses	3 (1%) 997 (1%)	3 (1%) 669 (0%)	1 (0%) 332 (0%)	33 (9%) 10 011 (7%)	8 (2%) 1 759 (1%)	31 (8%) 10 402 (7%)	25 (7%) 7 392 (5%)	81 (22%) 42 483 (29%)	133 (36%) 55 752 (38%)	41 (11%) 13 651 (9%)	9 (2%) 3 153 (2%)	0 (0%) 0 (0%)	368 (100%) 146 601 (100%)
Blocks of flats	8 (2%) 2 485 (1%)	7 (1%) 1 924 (1%)	9 (2%) 1 928 (1%)	106 (22%) 24 806 (10%)	66 (14%) 17 877 (7%)	101 (21%) 30 115 (12%)	86 (18%) 52 287 (21%)	47 (10%) 51 001 (20%)	39 (8%) 58 555 (23%)	14 (3%) 13 161 (5%)	1 (0%) 337 (0%)	0 (0%) 0 (0%)	484 (100%) 254 476 (100%)
Dormitories	18 (8%) 5 155 (6%)	0 (0%) 0 (0%)	1 (0%) 477 (1%)	8 (3%) 1 771 (2%)	9 (4%) 2 396 (3%)	19 (8%) 5 041 (6%)	9 (4%) 10 502 (13%)	25 (10%) 8 374 (10%)	66 (28%) 22 625 (28%)	55 (23%) 12 698 (15%)	20 (9%) 11 576 (14%)	5 (2%) 1 533 (2%)	235 (100%) 82 148 (100%)
Holiday cottages	26 (0%) 1 651 (1%)	47 (1%) 2 715 (1%)	33 (0%) 1 974 (1%)	520 (7%) 27 939 (10%)	416 (6%) 17 589 (7%)	664 (10%) 26 485 (10%)	1 426 (21%) 49 651 (19%)	1 496 (22%) 52 375 (20%)	1 286 (19%) 46 455 (17%)	657 (9%) 24 398 (9%)	285 (4%) 11 187 (4%)	89 (1%) 4 239 (2%)	6 945 (100%) 266 658 (100%)
Utility buildings	141 (1%) 7 049 (1%)	296 (2%) 11 797 (2%)	192 (1%) 7 940 (1%)	837 (6%) 39 174 (6%)	1 028 (7%) 41 395 (7%)	1 797 (13%) 73 456 (12%)	2 557 (18%) 100 550 (16%)	1 536 (11%) 117 800 (19%)	2 532 (18%) 109 242 (18%)	1 528 (11%) 60 439 (10%)	985 (7%) 32 329 (5%)	401 (3%) 13 850 (2%)	13 830 (100%) 615 021 (100%)
Commercial and office buildings	9 (0%) 2 269 (0%)	12 (1%) 6 360 (1%)	10 (0%) 1 564 (0%)	111 (5%) 34 468 (3%)	91 (4%) 52 191 (5%)	112 (5%) 72 343 (6%)	222 (11%) 121 404 (11%)	379 (18%) 245 845 (22%)	459 (22%) 400 537 (35%)	469 (22%) 115 713 (10%)	187 (9%) 56 925 (5%)	53 (3%) 18 685 (2%)	2 114 (100%) 1 128 304 (100%)
Public buildings	10 (1%) 3 554 (0%)	10 (1%) 2 106 (0%)	11 (1%) 3 723 (0%)	76 (7%) 31 321 (4%)	48 (5%) 26 676 (3%)	70 (7%) 79 253 (9%)	123 (12%) 136 304 (16%)	166 (16%) 199 211 (23%)	188 (18%) 162 569 (19%)	181 (17%) 127 116 (15%)	83 (8%) 63 553 (7%)	77 (7%) 35 634 (4%)	1 043 (100%) 871 020 (100%)
Warehouses	4 (0%) 1 641 (0%)	15 (1%) 3 159 (0%)	12 (1%) 7 235 (1%)	63 (5%) 24 791 (3%)	63 (5%) 41 943 (4%)	92 (7%) 34 719 (4%)	163 (12%) 81 013 (8%)	170 (12%) 189 775 (19%)	257 (19%) 264 098 (27%)	303 (22%) 219 198 (22%)	169 (12%) 88 236 (9%)	67 (5%) 31 195 (3%)	1 378 (100%) 987 003 (100%)
Industrial buildings	5 (0%) 2 106 (0%)	6 (0%) 2 554 (0%)	2 (0%) 4 010 (0%)	65 (5%) 89 699 (5%)	48 (4%) 64 367 (4%)	93 (7%) 119 422 (7%)	129 (10%) 226 585 (14%)	197 (15%) 407 319 (25%)	266 (21%) 325 937 (20%)	315 (25%) 290 017 (18%)	111 (9%) 71 657 (4%)	44 (3%) 50 396 (3%)	1 281 (100%) 1 654 069 (100%)
Agricultural buildings	9 (1%) 4 029 (1%)	15 (2%) 3 312 (1%)	18 (2%) 3 300 (1%)	38 (4%) 7 521 (2%)	39 (5%) 8 249 (3%)	33 (4%) 4 902 (2%)	64 (8%) 15 438 (5%)	52 (6%) 23 360 (7%)	111 (13%) 54 615 (17%)	273 (32%) 120 025 (37%)	143 (17%) 57 930 (18%)	47 (6%) 19 430 (6%)	842 (100%) 322 111 (100%)
Transport buildings	6 (1%) 2 445 (0%)	5 (1%) 1 433 (0%)	3 (0%) 1 207 (0%)	32 (3%) 10 562 (2%)	18 (2%) 6 076 (1%)	44 (5%) 20 779 (4%)	112 (12%) 62 641 (11%)	183 (20%) 215 315 (37%)	160 (17%) 104 230 (18%)	213 (23%) 116 439 (20%)	106 (12%) 34 178 (6%)	33 (4%) 11 873 (2%)	915 (100%) 587 178 (100%)
Other buildings	1 (0%) 50 (0%)	12 (1%) 11 006 (9%)	2 (0%) 33 (0%)	29 (2%) 5 036 (4%)	19 (1%) 836 (1%)	19 (1%) 2 108 (2%)	60 (3%) 6 775 (6%)	72 (4%) 4 648 (4%)	1 493 (80%) 69 025 (58%)	81 (4%) 12 163 (10%)	47 (3%) 4 713 (4%)	26 (1%) 2 471 (2%)	1 861 (100%) 118 864 (100%)
Unknown buildings	2 (1%) 65 (0%)	2 (1%) 192 (0%)	2 (1%) 55 (0%)	26 (13%) 4 441 (7%)	13 (6%) 1 466 (2%)	23 (11%) 7 814 (12%)	12 (6%) 4 189 (7%)	11 (5%) 2 235 (4%)	81 (40%) 33 894 (54%)	23 (11%) 6 498 (10%)	9 (4%) 1 748 (3%)	1 (0%) 177 (0%)	205 (100%) 62 774 (100%)

Table 9. Building year by building type

4.6 Age of buildings at the time of demolition

Detached houses and blocks of flats showed the highest average ages of the demolished stock, over 60 years. Buildings classified as “others” had the shortest life spans, little over 30 years. Tables 10 and 11 show that NRB have a shorter life span than RB. However, these ages should not be confused with the average age of the whole stock that includes buildings that have been demolished prior to 2000 or after 2012 and buildings that still exist.

Name of the group	**Average age at the time of demolition (years)**
Residential buildings (RB)	58
Non-residential buildings (NRB)	43

Table 10. Average age at the time of demolition for RB and NRB

Building type	**Average age at the time of demolition (years)**
Detached houses	64
Row houses	44
Blocks of flats	62
Dormitories	36
Holiday cottages	47
Utility buildings	47
Commercial and office buildings	39
Public buildings	41
Warehouses	37
Industrial buildings	37
Agricultural buildings	35
Transport buildings	36
Other buildings	32

Table 11. Average age at the time of demolition by building type

In residential buildings, demolished row houses showed life spans two decades shorter than detached houses or blocks of flats. In non-residential buildings, the longest life spans occurred in utility buildings (47 years) and public buildings (41 years). All in all, over 80% of the demolished floor area was located in buildings that were less than 60 years old. Figure 4 shows the age division in detail and Figures 5 and 6 for RB and NRB.

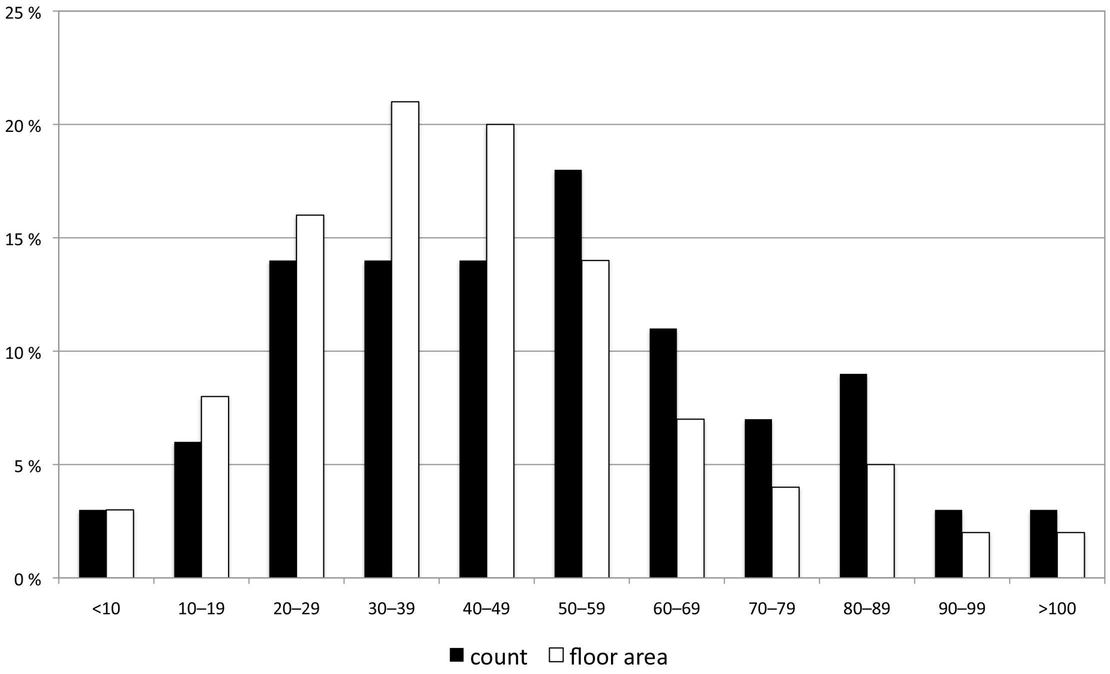

Figure 4. Shares of count and area of all buildings by age at the time of demolition

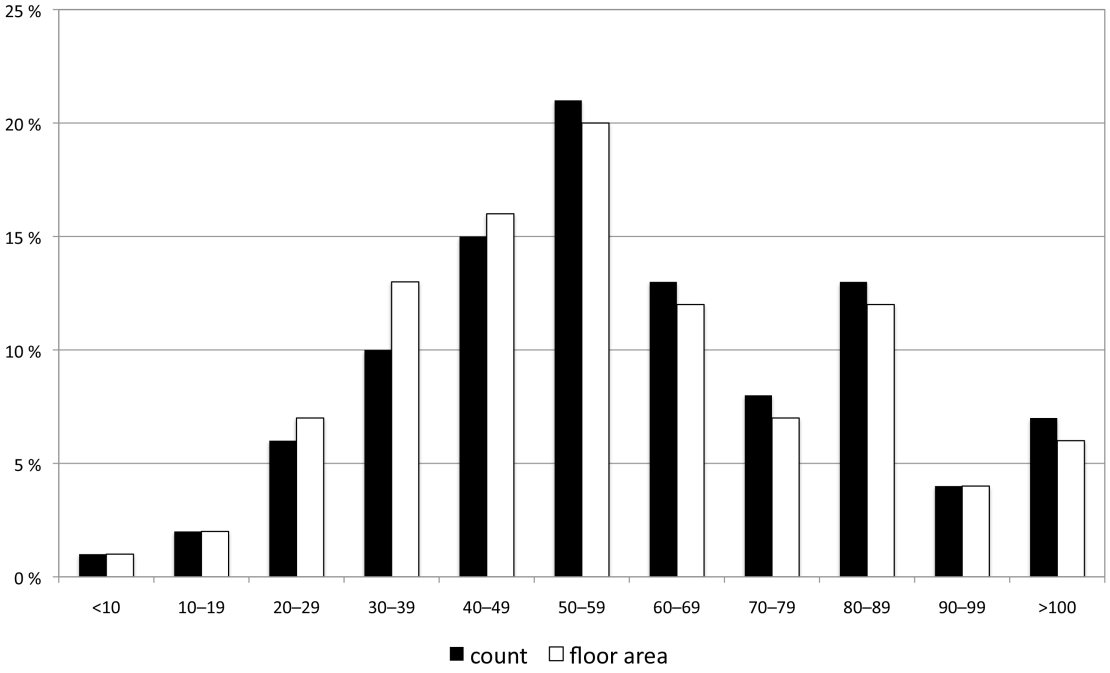

Figure 5. Shares of count and area of RB by age at the time of demolition

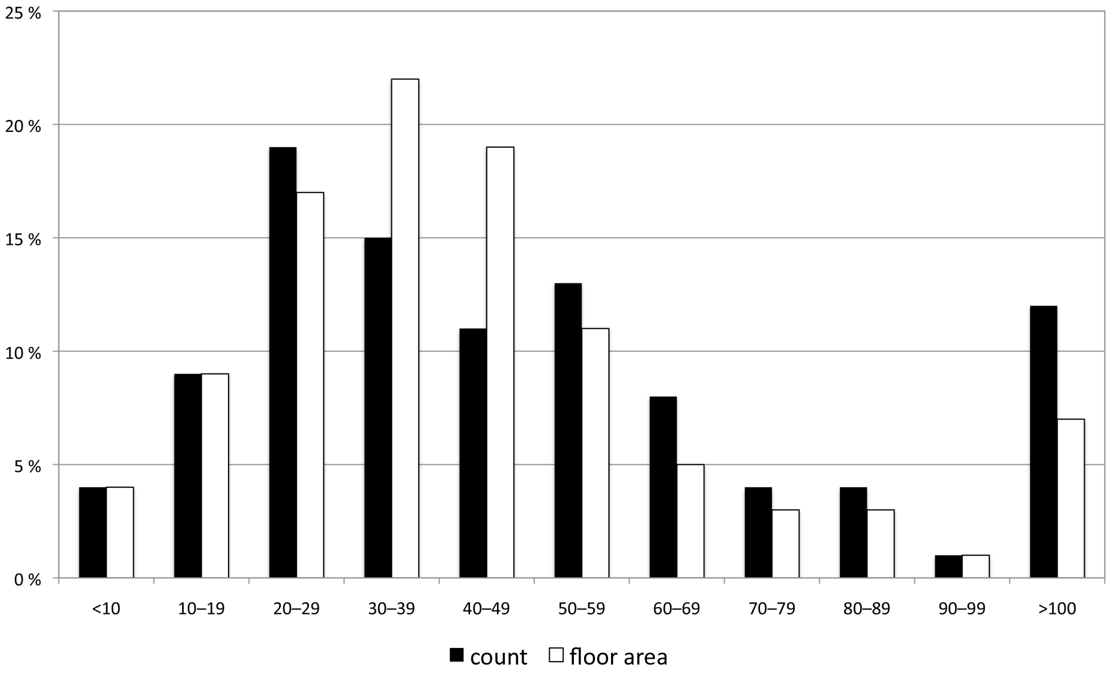

Figure 6. Shares of count and area of NRB by age at the time of demolition

4.7 Reported motives for demolition

As seen in Table 12, the data shows clearly that removals from the building stock are a result of conscious deliberation. The most usual reason for demolition was to give way for new construction. Destruction or abandonment explained only a small minority of demolition decisions. The group of "other reasons" was accountable for the rest. If measured in floor area, new construction and other reasons were equally significant.

Reason for demolition	Number	Percentage	Floor area	Percentage	Average area
New construction	24 134	47 %	4 237 690	47 %	176
Other reasons	22 415	44 %	4 213 535	47 %	188
Destruction	2 902	6 %	435 620	5 %	150
Abandonment	1 367	3 %	113 355	1 %	83

Table 12. Number and area of demolished buildings by reason for demolition

Table 13 shows that owners report new construction as the primary reason of demolition only in inner cities. In all other area types the category of other reasons is prevailing. Destruction is emphasized in cultivation countryside and sparsely populated countryside. However, in those areas, too, new construction and other reasons dominate over destruction. Table 14 presents the division of demolition reasons by the building decade of the demolished building. New construction prevails for demolished buildings built between 1940 and 1980. Other reasons, then again, dominate both the very distant and the quite recent decades.

Reason for demolition **number (%)** **floor area (%)**	**New construction**	**Other reasons**	**Destruction**	**Abandonment because of decay**	**Total**
Inner cities	6 019 (60%) 2 391 824 (60%)	3 791 (38%) 1 520 868 (38%)	72 (1%) 32 342 (1%)	81 (1%) 13 617 (0%)	9963 (100%) 3 958 651 (100%)
Outer cities	5 976 (49%) 817 182 (41%)	5 722 (47%) 1 090 434 (55%)	254 (2%) 66 932 (3%)	171 (1%) 20 643 (1%)	12 123 (100%) 1 995 191 (100%)
City rings	3 819 (46%) 311 541 (36%)	3 912 (47%) 482 002 (56%)	414 (5%) 57 883 (7%)	176 (2%) 11 366 (1%)	8 321 (100%) 862 792 (100%)
Rural towns	783 (39%) 155 601 (34%)	1 026 (51%) 267 423 (58%)	158 (8%) 28 698 (6%)	55 (3%) 6 969 (2%)	2 022 (100%) 458 691 (100%)
Countryside near cities	3 005 (47%) 205 485 (37%)	2 650 (41%) 269 611 (49%)	510 (8%) 58 628 (11%)	221 (3%) 15 548 (3%)	6 386 (100%) 549 272 (100%)
Cultivation countryside	2 634 (38%) 235 409 (31%)	3 157 (46%) 372 603 (50%)	727 (11%) 117 921 (16%)	375 (5%) 24 255 (3%)	6 893 (100%) 750 188 (100%)
Sparsely populated countryside	1 884 (37%) 118 876 (28%)	2 146 (42%) 209 787 (50%)	764 (15%) 72 998 (17%)	288 (6%) 20 957 (5%)	5 082 (100%) 422 618 (100%)

Table 13. Reason for demolition by area type

Building year number (%) floor area (%)	New construction	Other reasons	Destruction	Abandonment	Total
2000 -	281 (31%) 45 398 (49%)	423 (46%) 109 638 (55%)	212 (23%) 44 669 (22%)	4 (0%) 206 (0%)	920 (100%) 199 912 (100%)
1990 - 1999	817 (36%) 120 045 (26%)	1 081 (47%) 283 756 (62%)	384 (17%) 52 691 (12%)	18 (1%) 1 055 (0%)	2 300 (100%) 457 547 (100%)
1980 - 1989	1 821 (40%) 491 769 (42%)	2 231 (49%) 577 468 (49%)	466 (10%) 104 882 (9%)	57 (1%) 10 749 (1%)	4 575 (100%) 1 184 868 (100%)
1970 - 1979	3 910 (49%) 967 486 (53%)	3 638 (46%) 782 200 (43%)	321 (4%) 52 059 (3%)	95 (1%) 9 758 (1%)	7 964 (100%) 1 811 503 (100%)
1960 - 1969	3 310 (56%) 972 127 (56%)	2 259 (38%) 698 746 (41%)	232 (4%) 40 990 (2%)	124 (2%) 10 517 (1%)	5 925 (100%) 1 722 380 (100%)
1959 - 1959	4 645 (54%) 641 786 (55%)	3 308 (39%) 493 354 (42%)	373 (4%) 40 630 (3%)	199 (2%) 13 999 (1%)	8 525 (100%) 1 162 769 (100%)
1940 - 1949	2 981 (49%) 354 736 (48%)	2 589 (43%) 335 129 (46%)	260 (4%) 26 576 (4%)	224 (4%) 18 830 (3%)	6 054 (100%) 735 271 (100%)
1930 - 1939	1 727 (47%) 173 879 (41%)	1 635 (45%) 224 715 (53%)	157 (4%) 14 191 (3%)	150 (4%) 8 675 (2%)	3 669 (100%) 421 460 (100%)
1920 - 1929	2423 (43%) 241 193 (41%)	2 615 (47%) 297 291 (51%)	281 (5%) 30 702 (5%)	262 (5%) 17 678 (3%)	5 581 (100%) 586 864 (100%)
1910 - 1919	259 (45%) 23 712 (39%)	284 (49%) 31 984 (53%)	26 (4%) 3 112 (5%)	19 (3%) 1 346 (2%)	582 (100%) 60 154 (100%)
1900 - 1909	339 (46%) 37 409 (50%)	343 (46%) 30 253 (40%)	32 (4%) 5 561 (7%)	31 (4%) 1 614 (2%)	745 (100%) 74 837 (100%)
- 1899	1 621 (41%) 168 150 (30%)	2 009 (51%) 349 001 (63%)	158 (4%) 19 557 (4%)	184 (5%) 18 928 (3%)	3 972 (100%) 555 636 (100%)

Table 14. Reason for demolition by age

4.8 Correspondence to new construction

Table 15 summarizes the findings a comparison between the reasons for demolition provided by the owner and actualized or planned new construction on the sites of the removed buildings. According to the data, 32 008 new buildings with 9 975 129 m^2 of floor space had been constructed on 18 183 pieces of real estate by August 2013. In addition to the finished buildings, 8010 building permits with 1 848 126 m^2 had been granted for 5313 properties between January 2000 and August 2013. 54% of the permits were still valid.

Reason for demolition	New construction	Building permits	Permits valid	Number of properties	Demolished buildings	Demolished floor area	Built buildings	Built floor area	Planned buildings	Planned floor area
New construction (NC)	yes	yes	yes	912	1 552	304 784	3 006	908 150	1939	341 592
New construction	yes	yes	no	772	1 112	178 938	1 222	502 462	907	305 904
New construction	yes	no	-	10 710	13 799	1 913 512	18 159	5 485 198	0	0
New construction	no	yes	yes	844	1 031	184 132	0	0	1246	391 246
New construction	no	yes	no	748	864	74 733	0	0	955	120 546
New construction	no	no	-	5 454	7 245	1 987 848	0	0	0	0
Total, NC				**19 440**	**25 603**	**4 643 947**	**22 387**	**6 895 810**	**5047**	**1 159 288**
Other	yes	yes	yes	561	796	137 714	1 427	569 109	999	240 731
Other	yes	yes	no	392	501	92 012	819	294 648	488	55 587
Other	yes	no	-	4 836	5 862	1 038 854	7 375	2 215 562	0	0
Other	no	yes	yes	602	683	123 430	0	0	876	237 520
Other	no	yes	no	482	547	82 217	0	0	600	155 000
Other	no	no	-	13 322	16 826	2 882 026	0	0	0	0
Total, other				**20 195**	**25 215**	**4 356 253**	**9621**	**3 079 319**	**2963**	**688 838**
Total, both				**39 635**	**50 818**	**9 000 200**	**32 008**	**9 975 129**	**8010**	**1 848 126**

Table 15. Motive for demolition by actualized or planned new construction

When new construction was given as a motive to demolish, new construction was actually realized in nearly two thirds of the real estates. A permit had been applied for in additional 8%. All in all, in 72% of the properties steps towards new construction had been taken as planned. On the other hand, when motives other than new construction were provided, new construction had followed on under one third of the properties. In addition, a permit had been applied for in another 5%. In other words, no steps towards new construction had been taken in two thirds of the cases. To summarize, little over 1/4 of the properties that had planned new construction did not go forward, and roughly 1/3 of properties that demolished for other reasons ended up with new construction, nonetheless. When new construction was named the reason for demolition, nearly 1,5 times the amount of the old floor area was built. When other reasons were provided, 0,7 times the old floor area was constructed. In total, the amount of built floor area exceeds demolished floor area by 10%.

In the majority of the cases, the number of new buildings equalled the number of demolished buildings. The number of new buildings was greater than the number of demolished buildings in 31%, and smaller in 10%. New construction usually meant the addition floor area. Floor area was reduced for 15% of the properties and remained the same for 1%.

4.9 Simultaneous new construction in the community

In addition, the amounts of demolished and newly constructed floor areas in the municipality were compared in 10 building groups. When floor area of all buildings groups is summed up, new construction exceeds demolition in all 320 Finnish municipalities. This applies to the group of detached houses as well. In other building groups there are only 8–25 municipalities in which more demolition than new construction had taken place. In most cases, the overrun is not significant. When it comes to row houses, blocks of flats and the group of commercial, office and dormitory buildings, these municipalities are small and peripheral. For holiday cottages and agricultural buildings, the municipalities include unsurprisingly cities in Southern Finland. The demolition of public buildings exceeds new construction in some small towns and peripheral rural municipalities. In the groups of industrial and warehouse buildings as well as traffic buildings and other buildings, both cities and rural municipalities are represented.

4.10 Demolition of apartments

As seen in table 16, 28 158 apartments (an average of nearly 2350 apartments per year) have been demolished since 2000, the majority of them in detached houses. 61% of removed apartments were located in growing municipalities, which dominate the demolition of apartments in all building types. The share of apartments demolished from blocks of flats is highest in growing municipalities and lowest in steady-state communities. Table 17 elaborates on the location of demolished apartments within zones of different degree of urbanization. Inner cities prevail in the demolition of apartments in all other building types except in detached houses, apartments in which were demolished in greatest numbers in outer cities. Inner cities clearly stand out for blocks of flats, as every third apartment demolished in city cores was located in them.

Demolished apartments, number	**In detached houses**	**In row houses**	**In blocks of flats**	**In NRB**	**Area, total**
Growing (97)	10 532 (61%)	1 235 (7%)	3 484 (20%)	1 975 (11%)	17 226 (100%)
Steady-state (30)	1 665 (69%)	292 (12%)	240 (10%)	207 (9%)	2 404 (100%)
Shrinking (193)	5 805 (68%)	837 (10%)	1 206 (14%)	680 (8%)	8 528 (100%)
Total	18 002 (64%)	2 364 (8%)	4 930 (18%)	2 862 (10%)	28 158 (100%)

Table 16. Demolished apartments in growing and shrinking areas and different building types

Demolished apartments, number	**In detached houses**	**In row houses**	**In blocks of flats**	**In NRB**	**Total**
Inner cities	3 853 (47%)	533 (6%)	2 547 (31%)	1 323 (16%)	8 256 (100%)
Outer cities	4 499 (73%)	410 (7%)	789 (13%)	482 (8%)	6 180 (100%)
City rings	2 529 (80%)	209 (7%)	200 (6%)	224 (7%)	3 162 (100%)
Rural towns	971 (51%)	221 (12%)	448 (23%)	267 (14%)	1 907 (100%)
Countryside near cities	1 690 (65%)	321 (12%)	388 (15%)	191 (7%)	2 590 (100%)
Cultivation countryside	2 872 (75%)	424 (11%)	307 (8%)	238 (6%)	3 841 (100%)
Sparsely populated countryside	1 584 (71%)	246 (11%)	251 (11%)	137 (6%)	2 218 (100%)
Building type, total (100%)	18 002 (64%)	2 364 (8%)	4 930 (18%)	2 862 (10%)	28 158 (100%)

Table 17. Demolished apartments in different building types by different zones of urbanization

4.11 Correlations

To understand the dynamics between community size, demographic change, new construction and demolition, several correlations were calculated for these parameters. Firstly, it needs to be noted that the number of inhabitants of Finnish municipalities (in 2000) and the demographic change (change in the number of inhabitants between 2000 and 2012) correlates linearly (r=0,86). Not surprisingly, there is a positive linear correlation between the floor area built during the examination period and the number of inhabitants in 2012 (r=0,96), the change in the number of inhabitants (r=0,94) as well as the total floor area of the building stock (r=0,95).

Demolished floor area correlates strongly alike (r=0,98) with the number of inhabitants (Figure 7), demographic change (r=0,88), built floor area (r=0,94) and total floor area in the stock (r=0,97). The number of demolished apartments correlates, too, with the number of inhabitants (r=0,91) and the demographic change (r=0,85). In other words, the larger the city, the more it has gained population during the 2000s, the more has been built and the more has been demolished. In reverse manner, the smaller the municipality, the less it has grown (or even shrunk), the less has been built and the less has been demolished. In the Finnish context, the amount of demolition, the size of the community, its demographic development and construction activity are all interconnected.

However, in order to understand the big picture in shrinking municipalities, it must be remembered that neither new construction nor the expansion of settlements has seized in them. One could expect that the greater the losses in population, the higher the replacement rate (demolished area per built area), as a high replacement rate proposes that the main role of new construction would be to replace obsolete buildings. Remarkably, no linear correlation (r=0,00) was found for the replacement rate and the change in the number of inhabitants.

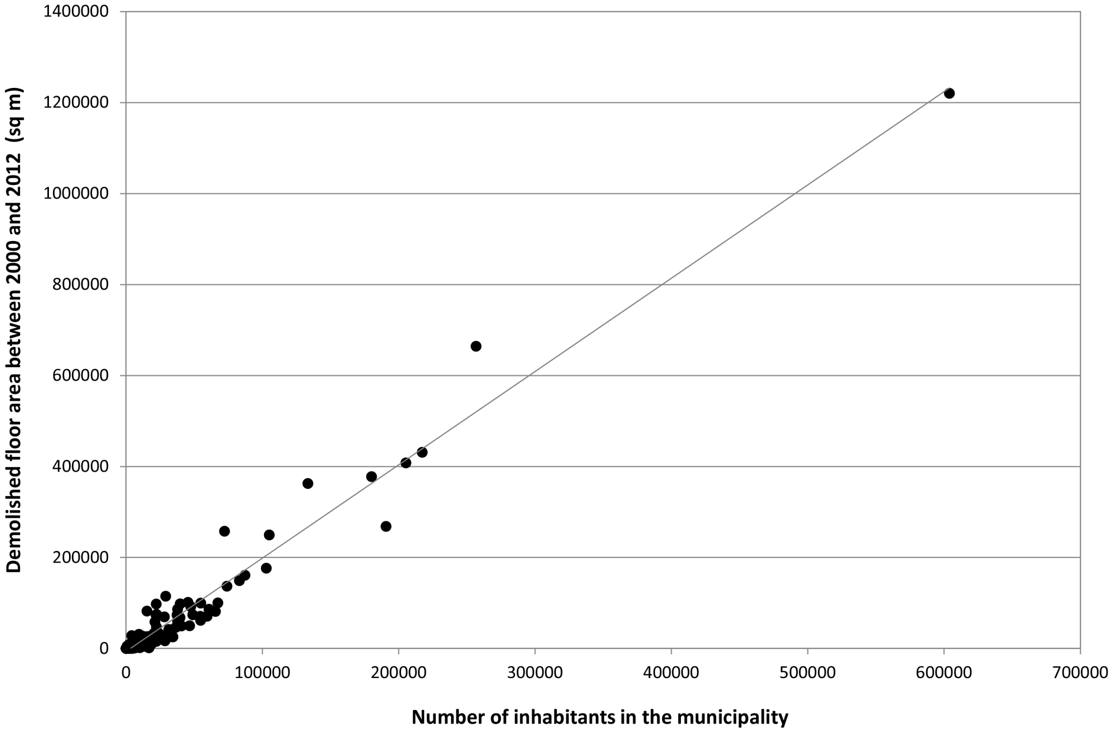

Figure 7. Number of inhabitants in municipality by demolished floor area

5 Discussion

5.1 On demolition patterns and building age

Finland's demolition rate was found to be among the highest when compared to other Western European countries (as listed in Thomsen & van der Flier, 2011). The demolition rate was higher for NRB than for RB, which coincides with Bradley and Kohler's (2007) findings; however, the rate for NRB was four times the rate of RB, not tenfold as in their case study. NRB were found to have a shorter life span than RB, which conforms with Bradley and Kohler's (2007) model and Thomsen and van der Fliers (2009 & 2011) arguments. The age distributions for the demolished floor area of the whole stock (Figure 4, white columns) as well as for NRB (Figure 6, white columns) showed right skewed distributions. This supports Bekker's (1978) argument about Weibull distribution being more appropriate for modelling than normal distribution. However, the age distribution presented in this study is not directly comparable to survival functions, as it does not take into account buildings that still exist, which may have a non-negligible effect according to Bradley & Kohler (2007). The age distributions for RB and residential floor area (Figure 5) can also be interpreted to be right skewed, because the peak in category 80–89 is explained by the fact that a significant amount of pre-industrial buildings has been recorded to year 1920. This also explains the double-peaked distribution for all buildings in count (Figure 4, black columns), but not the second peak for NRB in count (Figure 5, black columns) in the category of 50–59 years.

Two characteristic situations out of three as listed by Thomsen et al. (2011) were detected: growth and shrinkage. This study reasserts what Thomsen (2009) and Huuhka (2013) had found about most demolition taking place in tight markets, which suggests that land value is a significant driver. The paper also documents with another data that the same that Huuhka (2013) had concluded about building stocks having kept growing in the shrinking settlements of Finland — a phenomenon that is likely linked to shrinkage sprawl and land value as discussed in the background. However, the third type, i.e. ‘intensive transformation’ in the form of large-scale demolitions of mass housing, was not observed.

A better understanding about the age distribution of demolished buildings as well as the motives behind demolition decisions for different building types can be helpful in developing methodology for more accurate service life estimation. In theory and LCA, different life spans for RB and NRB are usually assumed, which appears to be justified in the light of the results of this paper. Adaptive reuse from NRB to RB shows an obvious opportunity to extend the average age of buildings at the time of demolition, as according to Bradley and Kohler (2007), there is no reason to expect that NRB would be physically less robust than RB. Because these transformations are relatively rare (Bradley & Kohler, 2007), more research on their prerequisites would be needed.

5.2 On motives for demolition

Alas, the indications about the motives for demolition in the data were quite vague. Despite this shortcoming, it is undisputable that the vast majority of demolition has occurred as a result of conscious deliberation. Regrettably, the data does not touch upon the condition of the building; it is not possible to say if the owners wish to execute new construction as a result of bad condition or despite good condition. In addition to condition, several other motives may explain demolition because of 'other reasons': a desire to clear the plot for sale (which is indirectly connected to new construction), a need to make way for the construction of new infrastructure or a disinterest or a lack of (financial) means for maintenance. Nevertheless, the data allows interpreting that other reasons could refer to some extent to the condition of the building, as they dominate the reported demolition motives for buildings that were built either quite recently or very long time ago. On one hand, very new buildings would likely not be demolished unless there was something wrong with their condition; on the other hand, problems with the condition can be expected to occur more the older the building is. New construction, then again, prevails for demolished buildings built between 1940 and 1980, which are old enough to fall behind with current technical and functional desires. The comparison with actualized and planned new construction on the plots of demolished buildings offers support for this interpretation.

5.3 On prerequisites for recycling and reuse

Construction material supply and demolition waste treatment are typical features in which cities are not self-sufficient but have to rely on their hinterlands. Because Finland is a sparsely populated country nearly 1200 km long and over 500 km wide, long distances contribute to economic and environmental costs of transporting raw materials and demolition waste. As the results indicate that new construction exceeds demolition in nearly all municipalities and building groups, the prerequisites for reusing components locally exist from this point of view. In addition, 3/4 of demolished square meters were found to be concentrated in cities that cover only 5% of the country. In cities, a remarkable share of the removed structures consisted of large and newish NRB made of durable industrial materials (concrete, steel). This indicates a potential for adding urban resilience via harvesting components for reuse: unlike landfilling and recycling, reuse does not require the materials to be transported beyond city borders for heavy treatments. Steel and concrete NRB often have connections that are rather suitable for deconstruction per se. However, if buildings were to be relocated or components reused, all the norms of new construction would currently apply. It would be worthy of policy-makers to reflect on whether this requirement is always reasonable in the light of the relatively short average age of certain structures. If the demolished stock is to be regarded as a reserve for raw materials or parts (as suggested by Kohler & Hassler, 2002 and Thomsen et al., 2011), more in-depth knowledge is still needed about the composition of that stock. Vintage cohorts i.e. material and components inventories characteristic to specific building types and ages (as suggested in Kohler & Hassler, 2002 and used in Holck Sandberg et al., 2014) could be helpful in this work.

5.4 On prerequisites for adaptive reuse

Although new construction activity is hardly a private matter in the Western world, demolition is something that policies do not usually address. Yet, literature suggests that replacement of buildings would to contribute negatively to the same phenomena that authorities aim to control by regulating new construction: to energy use (Fuller & Crawford, 2011; Heinonen, Säynäjoki, Kuronen & Junnila, 2012; Heinonen, Säynäjoki & Junnila, 2011; Itard & Klunder, 2007; Power, 2008 & 2010; Thomsen & van der Flier, 2009), urban quality and sprawl (Huuhka, 2013; Mallach, 2011; Reckien & Martinez-Fernandez, 2011) as well as social justice (Gilbert, 2009; Power, 2008 & 2010). Given this knowledge, replacement of buildings should not be taken for granted in urban development policy making. As Kohler and Hassler (2002, p. 231) put it, these stocks

> *'represent cultural as well as ecological resources which typically are not put into use due to ignorance about the possible transformation and adaptation.'*

In this study, the analyses show that demolition focuses on city cores and that it is connected to growth, which suggests that Finnish urban consolidation would rely largely on replacement of buildings. This may not be helpful for achieving the climate change mitigation targets, as case studies suggest (Heinonen et al., 2011 & 2012). Interestingly, demolition of apartments was also concentrated on tight markets of cities that are known to suffer from housing shortages. The fact that new construction had exceeded demolition in Finnish municipalities by rule indicates that the need for space had not decreased, which is an obvious precondition for adaptive reuse. While it can be reasonably expected that the need for space is factually growing in demographically growing municipalities, the increase of building stocks in shrinking municipalities may be explained with the vicious circle of townscape decay and sprawl as literature suggests. These patterns and phenomena should be recognized by urban planners in growing and shrinking municipalities alike.

Remarkably, NRB types showed short average lives of roughly 40 years, although they were usually made of durable industrial materials and represented the largest buildings in the data. Although the data was quite general on demolition causes, it allowed interpreting that a significant share of demolition would likely not be due to the condition of the building. This kind of knowledge about the characteristics of demolished buildings should be an important factor in deciding whether planning should opt for repurposing, extension and infilling or demolition and new construction.

Conclusions

All in all, this paper shows a variety of characteristics that help policy makers and urban planners to understand the quality of demolished buildings better and to adjust their position on replacement of buildings accordingly. The five hypotheses of the study were shown true. Between 2000 and 2012, demolition in Finland was connected to demographics (the more inhabitants the municipality had or gained, the more was demolished). Secondly, demolition was linked to new construction (the more was built, the more was demolished). Thirdly, demolition was related to the type and size of the settlement (the larger and the more urbanized the settlement, the more was demolished) and fourthly, to the type of buildings (demolition rate was higher for NRB than for RB). Finally, demolition did not primarily depend on the age of buildings (NRB were demolished at a younger age than RB). Dynamic models are usually based on the first and second hypothesis although there has been little empirical evidence. Thus, these results can help to validate these models. The results also present new information about the lifetime distribution of demolished buildings, which may help to improve the models. In further research, knowledge on vintage cohorts should be collected to allow using the evidence from this paper in material flow and life cycle analyses. These calculations could deepen further the understanding about reuse potential in building stocks. Combining the results from these analyses with predictions of future demolition could help plan future waste prevention and recovery policies better.

In addition, the coupling of new construction and demolition should be recognized in sustainable urban development policy making. Demolition was observed to be linked to two characteristic situations documented in earlier research — growth and shrinkage — but not to the third one, i.e. intensive transformation. Demolished buildings were found to be geographically highly concentrated: cities covering less than 5% of Finland were accountable for 76% of demolished floor area. In addition, 29% of demolished floor area was removed from pieces of real estate that represented only 5% of all plots that had undertaken demolition. Growth centres dominated the removals of most building types, especially NRB. Although the distribution into residential and non-residential floor area followed the degree of urbanization of the settlements, growth centres dominated the removals of apartments in absolute numbers. Comparing demolished buildings to the existing stock would raise the explanatory value of the data, but the available statistics on Finnish building stock are not detailed enough to allow the comparison. The collection of that data presents a challenge for future research.

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ORIGINAL PAPERS

II

VACANT RESIDENTIAL BUILDINGS AS POTENTIAL RESERVES? A GEOGRAPHICAL AND STATISTICAL STUDY

by

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Abstract

Vacant housing has been associated with a variety of interests from economic implications and consequences for the urban structure to the possibility to provide housing for the homeless. In addition to the social and financial aspects, unused buildings have resources embedded in them. They take up land from other activities and contain refined natural resources in the form of building components and materials. Therefore, empty buildings can be regarded as reserves for housing and urban mining, *i.e.* material extraction. In doing so, these buildings contribute to the resilience of cities. This geographical and statistical study on residential vacancies is situated in Finland, a Northern country, where empty homes may also keep using energy and producing emissions. The research material consists of a vast data set of all residential buildings with vacancies in Finland in mid-2014, a total of 275 486 buildings with 1 100 267 occupied and 378 802 unoccupied dwellings (52% of the Finnish housing stock). The paper shows several characteristics that increase understanding on vacancies and their role in the dynamics of the building stock. Vacancy is an issue policies should address, not only because of social and economic implications, but also its environmental impacts and opportunities.

1 Introduction

Urban resilience can be defined as a city's buffering capacity to changed conditions. The building stock undeniably affects resilience. A vacant building is a building in transition – a potentially usable building that contributes to resilience or as a sign of degeneration that deteriorates resilience. For example, Kohler and Hassler (2002) have stated that obsolete parts of building stocks can act as reserves for current and future needs. Wyatt (2008) has observed a growing political interest in vacant English housing because empty dwellings are seen as waste of resources. Thomsen and van der Flier (2011) have remarked that the assessment of buildings' use value should not be based only on the present performance but also on the potential for adaptation.

On the other hand, vacant buildings are often seen to increase social and environmental problems, as they may contribute to the increase of vandalism, dereliction and deterioration (Remøy & van der Voordt, 2007; Wyatt, 2008). Morckel (2013) states that abandonment of properties worsens neighbourhood decline. In US, vacant homes have been found to lower the value of the surrounding properties even if the empty buildings are not decaying (Whitaker & Fitzpatrick, 2012, pp.35–36). Thus, it is perhaps not surprising that Thomsen and van der Flier (2011) have found that policies often prioritize demolition over other alternatives. Clearances have been used as a tool from Haussmann's 19th century Paris to today's France, Britain, US and the Netherlands (Kruythoff, 2003; Power, 2008; Gilbert, 2009; Mallach, 2011). But even when obsolete buildings are demolished, Thomsen and van der Flier (2011) consider that they can still be seen as resources for 'urban mining', *i.e.* the extraction of building components or materials. After all, demolition produces significant amounts of waste globally, and construction could act as a sink for this waste.

In the Waste Framework Directive of the European Union, prevention of waste is prioritized over preparation for reuse, and preparation for reuse over recycling as material (European Union, 2008, p.10). In the context of building stocks, reconstitution of abandoned buildings could be interpreted as prevention of waste, and component reuse as preparation for reuse. However, few tools exist to assess obsolete building stocks' potential for reutilization. Building stock models anticipate amounts of demolished buildings, not their characteristics; construction and demolition waste models predict mass flows, not the availability of components; and vacancy chain models simulate residential mobility with regard to consequences for housing markets, not housing stocks. In all, evidence-based knowledge about existing building stocks has long been considered as insufficient; accessing data on demolished or vacant parts of stocks has been found to be especially difficult (Kohler & Hassler, 2002; Kohler, Steadman & Hassler, 2009; Thomsen, Schultmann and Kohler, 2011). Nevertheless, Thomsen et al. (2011) remind that buildings' end-of-life phase has large quantitative and qualitative significance, despite the inadequate attention so far.

Long-term vacancy can be seen as a transition phase between the in-use stock and the obsolete or demolished part of the stock. Therefore, investigating vacancies can help to increase understanding about the dynamics of the building stock. This paper takes advantage of Finnish vacancy data, which, despite its availability, has not been explored beyond the compilation of official statistics and occasional articles (*e.g.* Mukkala, 2002; Virtanen, 2002; Taipale, 2015). The purpose of the research is twofold. The main goal is to study the properties and location of vacant housing in Finland, but the paper also touches upon its possible futures by examining links between vacancy, demolition and new construction. Table 1 presents the detailed research questions. Based on previous literature, it is hypothesized that vacancy is related to (1) demographics; (2) location; (3) size of housing stock; (4) building type; and that vacancy is not straightforwardly related to (5) building age; or (6) demolition.

Theme	Question(s)	Motivation for question(s)
Extent of vacancy	What are the vacancy rates for Finland in general; for municipalities of different sizes; and for different tenure types? What is the size of the underutilized part of the stock when compared with annual volumes of new construction or demolition?	Magnitude of the underutilized housing stock in different contexts.
Building types	Does vacancy touch on different building types up to a different degree?	Distribution of vacancies in the housing stock; types of homes in the reserve
Duration of vacancy	What is the duration of vacancy in different building types? Which proportion of their vacancy is normal and how much is problematic?	Severity of vacancy and obsoleteness
Geography	How are vacant homes located geographically and with regard to urban and rural areas?	Location of reserves for homes or building parts and materials.
Tenure	Which submarkets does vacancy touch upon?	Landlords' interests and capacities with regard to vacancy.
Materials	What construction materials are prevailing in underutilized buildings? Which percentage of them is built with prefabrication technology?	Reworkability of used building materials, recycling and reuse potential. Preconditions for reuse of components instead of recycling as material.
Relationship with other variables of building stock	Is there correlation between vacancy and population, demographic change, size of the building stock, or demolition?	Vacancy as a part of the dynamics of the building stock.
Replacement behaviour	Assuming that vacant buildings become demolished, which buildings replace demolished buildings in different contexts?	Possible futures for vacant and/or obsolete buildings.

Table 1. Research questions and their motivation.

2 Background

2.1 Theoretical and empirical knowledge on vacancies

Vacancies participate in the functionality of housing markets, which is why most of the existing theory concentrates on the perspective of real estate economics. Markets are driven by supply and demand, which are assumed to be in equilibrium. According to this theory, prices rise and vacancies reduce when demand exceeds supply and vice versa. (Glaeser & Gyourko, 2005). However, a certain amount of empty homes ('natural', 'transaction' or 'frictional' vacancy') is always considered as necessary to allow residential mobility (Couch & Cocks, 2013). Since vacancies act as a market correction mechanism (Zabel, 2014), 'cyclic' vacancy occurs if there is an oversupply of housing (Couch & Cocks, 2013). This oversupply may become permanent, for instance, as a result of global redivision of labour and subsequent outmigration.

Moreover, studies are reporting about different contexts in which the equilibrium theory fails to explain how housing markets function (Zabel, 2014). In Spain and Malta, for instance, prices have risen despite of excessive vacancies (Hoekstra & Vakili-Zad, 2011; Vakili-Zad & Hoekstra, 2011). In addition, shortage and oversupply can occur simultaneously (see *e.g.* Lauf, Haase, Seppelt & Schwarz, 2012). This is because, besides the aforementioned 'natural' and 'cyclic' vacancies, vacancy can be caused by unsuitability for prevailing market conditions based on the properties of housing, such as location, type or tenure ('structural vacancy') (Couch & Cocks, 2013). Therefore, more understanding is needed about the drivers, characteristics and implications of vacancy in different contexts in order for sustainable policies to be practiced on housing stocks and spatial planning.

Lately, the interest has also grown beyond the financial considerations to include socio-cultural aspects. For example, empty homes have been seen as an equity issue. The Guardian has raised awareness on empty homes in continental Europe and the UK. According to the figures collected from national censuses and other sources, there are 11 Million empty homes in Europe, double the number of homeless people (Neate, 2014). In Britain, vacant apartments could house one fourth of households in council house waiting lists (Griffits, 2010). The implications of vacancy have also been examined with regard to residential segregation (Großmann, Arndt, Haase, Rink & Steinführer, 2015) and the quality of life (Schetke & Haase, 2008).

In addition to the aforementioned financial and social aspects, research should acknowledge that vacant buildings have resources embedded in them. They keep taking up land and contain refined natural resources in the form of building components and materials. Although Thomsen and van der Flier (2011) regard obsolete buildings as resources for urban mining, they have reasoned that unused buildings on low value land will not become demolished. Supporting this theory, Huuhka (2014) has observed that the building stock as well as the area of human-occupied land has kept growing in all Finnish municipalities, despite the fact that two thirds of them have shrinking populations. Other authors have paid attention to new construction exacerbating the problem (Mukkala, 2002; Vakili-Zad & Hoekstra, 2011) as well as to the consequences of shrinkage sprawl, which empty buildings contribute to (Siedentop & Fina, 2010; Mallach, 2011; Reckien & Martinez-Fernandez, 2011).

Furthermore, in the Nordic conditions, including Finland, empty homes may keep using energy and, thus, producing emissions. Firstly, multi-family buildings in Finland have central heating systems, meaning that they must be heated fully despite the number of vacant flats. Secondly, empty buildings with water supply need to be kept heated at 5–15°C to prevent piping from freezing and bursting during the winter. Thirdly, retaining this ‘basic temperature’ is recommended even for buildings without water supply because of mould and frost damage prevention. As far as the current author knows, these resource- and energy-related environmental viewpoints still remain unaddressed.

2.2 How much vacancy is too much?

Theory acknowledges that natural vacancy rates may fluctuate in time and differ between markets and submarkets (Hagen & Hansen, 2010). For example, in the US, the countrywide rental vacancy rate has fluctuated between 5–11% and the homeowner vacancy rate between 1–3% since 1968 (US Census Bureau, 2014).

Nevertheless, 5% is usually considered as the upper limit for the normal mobility reserve (Glock & Häusermann, 2004). In Finnish social housing, a vacancy rate over 10% is considered as critical (Ympäristöministeriö, 2011, p.16). As seen in Table 2, gross vacancy rates often exceed these limits notably.

Country	**Vacancy rate (%)**
UK	3.6
US	10.4
Spain	13.9
Slovenia	14.0
Bulgaria	14.4
Malta	23.0
Italy	24.0
Germany (Western)	6.4
Germany (Eastern)	14.7
Czech	12.3
Estonia	6.2
France	6.8
Luxembourg	2.3
Poland	6.1
Portugal	10.8
Romania	11.6
Slovakia	11.6

Table 2. Vacancy rates in certain countries (years differ). Sources: Deilmann et al., 2009 (Germany); Norris & Shiels, 2004, p. 5 (Other countries); US Census Bureau, 2014 (US); Wyatt, 2008 (UK).

Geographically more detailed vacancy rates have been published for Britain and Spain. In the metropolitan areas of Northwest England, cities' vacancy rates land between 2–7% (Couch & Cocks, 2013). In Spain, the rates have been 7–19% for provinces and 4–27% for municipalities with more than 25 000 inhabitants (Hoekstra & Vakili-Zad, 2011). Even higher rates can occur in distressed areas. In Southern Italy, for example, a rate as high as 34% has been observed (Norris & Shiels, 2004, p.51). In Eastern Germany, the vacancy rate is more than double the rate in the West, and in the most precarious regions, vacancies may reach up to 50% of the building stock, as is the case with some neighbourhoods of Leipzig (Schetke & Haase, 2008).

2.3 How long vacancy is too long?

The US Census Bureau (2014) lists vacancies for time spans ranging from one month to two years or more. In Britain, vacancy of six months or more is referred to as long-term (Griffits, 2010; Couch & Cocks, 2013). In Finland, two time spans, two and six months, are used for monitoring vacancies in public housing (Ympäristöministeriö, 2011, p.15). As for the private housing stock in Finland, the average marketing time has not exceeded four months in the last ten years. Flats have the shortest and detached houses have the longest average marketing time, with row houses between the two. Since 2004, the maximum average marketing time has been 100 days for flats and 160 days for detached houses. In the most distressed towns of Finland, the latter has peaked at 9–12 months during the 10-year period. (Etuovi.com, 2014). In less central parts of the country, the sales time can be as much as two years (Tanskanen, 2014).

2.4 Where does vacancy take place?

Vacancy patterns are more or less country- and context-specific. The geographical location, building type and tenure are the main factors to consider, be that they are often intertwined. For instance, in Germany, vacancies concentrate on suburban GDR blocks and historical multi-storey dwellings (Glock & Häusermann, 2004; Deilmann et al., 2009), but in Slovakia, they focus on detached houses (Norris & Shiels, 2004, p.73). In Belgium, vacancies occur in city centres (Norris & Shiels, 2004, p.23) but in Finland, vacancies have been said to affect the peripheries (Mukkala, 2002).

In Europe, the highest vacancy rates have been observed in Southern and Eastern countries. While vacancies in the former have been associated with holiday residence, those in the latter have been explained with population decline in specific regions (Norris and Shiels, 2004, p.6). In the US, vacancy rates have generally been the highest in the South (US Census Bureau, 2014). In Italy, vacancies have likewise concentrated in the Southern and more rural part of the country (Norris & Shiels, 2004, p.51). In Norway, the vacancy rate has been found to increase the more peripheral the location and to correlate with the share of retirees. Therefore, it has been reasoned that the centralization process taken place in Norway between 1960–80s would show with delay in housing vacancies. (Nordvik & Gulbrandsen, 2009).

Moreover, public rental, private rental and owner-occupied housing are submarkets that have different demand. In Finland, vacancy is considered a problem of public housing (Ympäristöministeriö, 2011), while in Britain, the social housing sector has a lower vacancy rate than the private sector (Couch & Cocks, 2013). A study from Sweden shows that mobility between the submarkets can be very limited (Magnusson Turner, 2008), which offers one explanation for why housing shortage and oversupply can parallel.

2.5 Private and public policy responses

Besides demand, tenure also affects how landlords act in the face of vacancy. Proprietors can be divided into public professional, private professional and private non-professional owners, who have differing interests and capacities. Professional owners are motivated by their own asset management policies. In the case of private professional owners, policies can be traced back to yield, which is influenced by market potency and, indirectly, functional and technical quality of dwellings, since these factors affect rentability. Public owners can also be expected to foster social responsibility, although this is not always the case, while private non-professionals may be influenced by secondary motives such as emotional ties. (Thomsen & van der Flier, 2009). Their motives likely also differ depending on whether they use the dwelling as their home or if they rent it out. Furthermore, it should be noted that these dwellings also change their tenure type depending on the use, whereas tenures of professionally owned rental homes are of a more permanent nature.

In addition, proprietors' capability to conduct measures depends on the housing type. In multi-family buildings (row houses and blocks of flats), the decision-making is collective, whereas detached house owners and professional landlords usually have more freedom, since they tend to own the whole building. (Thomsen & van der Flier, 2009). However, the ownership of detached houses may also be dispersed between heirs or members of an undistributed estate, complicating the decision-making. To give an example of the range of the measures, the responses Finnish public housing companies have practiced to extensive vacancies include: increasing and targeting marketing; improving functionality; changing flat sizes and distribution; adaptive reuse as sheltered housing; selling to private buyers or property developers; and demolition (Ympäristöministeriö, 2011).

However, since long-term vacancy is 'a temporal mismatch between adjustments of the housing stock and regional change' (Nordvik & Gulbrandsen, 2009, p. 397), it has been pointed out that 'many housing problems cannot be solved using housing market policy tools alone as vacancy is caused by the general trends of depopulation and deindustrialization' (Glock & Häußermann, 2004). In East-German shrinking cities, public policies pursue consolidation of historical inner-city quarters and demolition of excess homes from large-panel blocks, but it has been questioned if the demand for these submarkets has been understood correctly (Glock & Häußermann, 2004; Grünzig, 2010). In UK, clearance and refurbishment policies have fluctuated over decades (Couch & Cocks, 2013). In US, tax foreclosure policies keep returning abandoned properties to market, but it has been argued that public interest requires more freedom of choice be given to authorities in this process to enable more sustainable social and urban development (Hackworth, 2014).

Nevertheless, public policy-making has not been limited exclusively to shrinkage contexts. In the 1970–80s, the authorities of Helsinki, Finland, strived for returning flats that were unauthorizedly turned into offices back to homes (Suvanto, 2013; Jääskeläinen, 2015). In England, the Housing Act 2004 allows council to force empty homes into use to alleviate housing shortage (Wyatt, 2008; Henderson, 2015).

2.6 Understanding Finland

To provide the reader an understanding about the study's context, a brief overview to Finland's conditions is necessary. The Finnish population of 5.5 million is divided between 320 municipalities. Figure 1 shows the map of Finland and the sizes of municipalities, ranging from 100 inhabitants to 613 000 inhabitants (the capital Helsinki in the South coast). The nine cities with over 100 000 inhabitants are considered as large; in addition, there are 11 mid-sized cities with 50 000–100 000 residents and 35 towns with 20 000–50 000 citizens. The average community size is 17 000 residents and the median is as little as 5800 residents. Two-thirds of the municipalities are shrinking. Shrinkage concentrates on rural communities, small towns and some rust-belt cities. (Statistics Finland, 2014).

The housing stock is among the youngest in Europe with only few percent built before 1920 (Hassler, 2009). Wood prevailed as a construction material until the 1950s and has dominated the construction of detached and row houses at all times (Siikanen 2008, pp.17–18). Wood construction methods consist of log construction (prevailing up to WWII) and balloon frames (dominant from 1945 on). The construction of multi-storey buildings was dominated by masonry structures until the late 1950s, when they became replaced by *in situ* cast concrete. Construction with precast concrete elements started in the 1960s and fully prefabricated frames took over during the 1970s. (Hytönen & Seppänen, 2009; Neuvonen, 2006). 44% of flats were built between 1960–79 and 39% after 1980 (Statistics Finland, 2014).

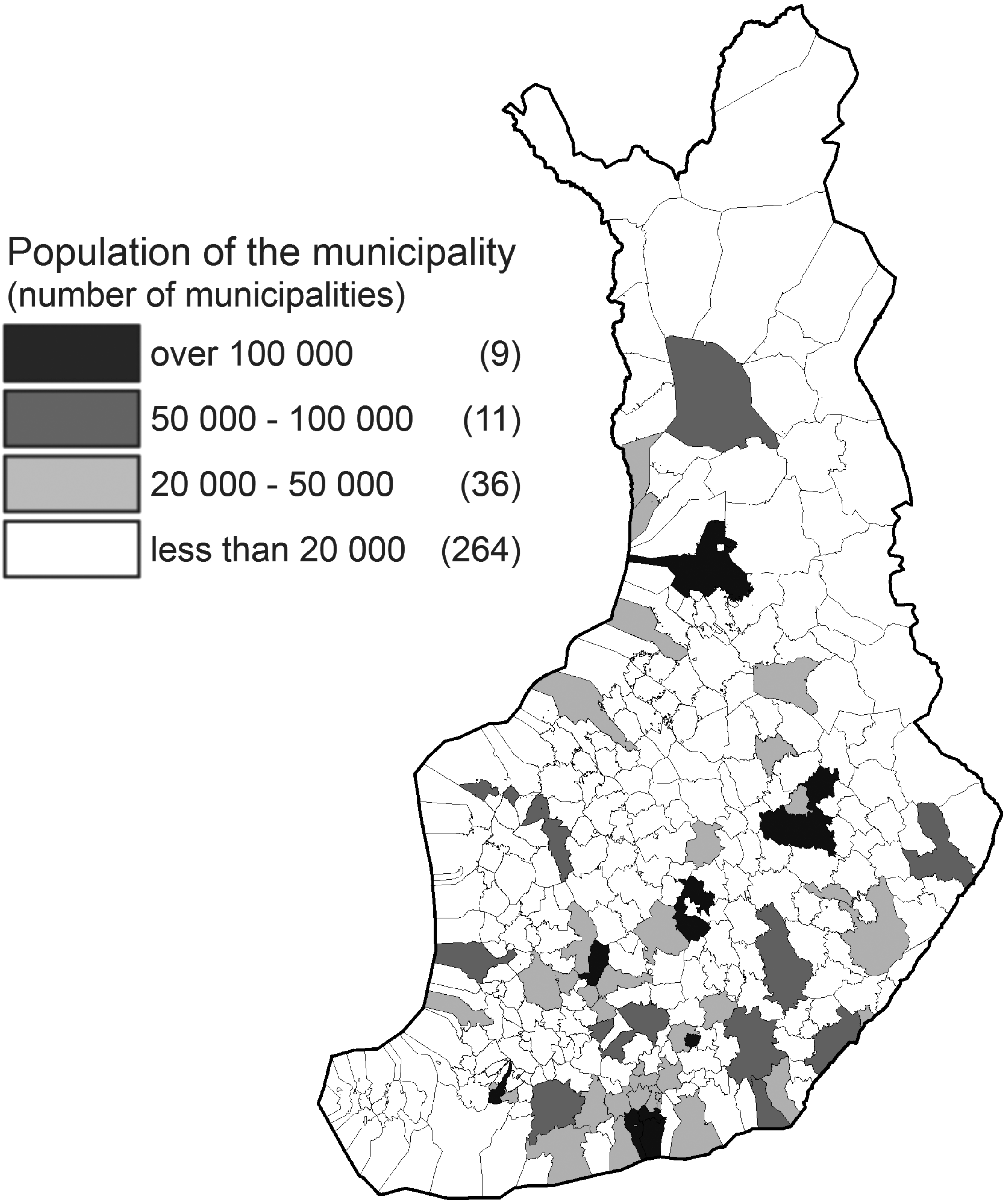

Figure 1. Map of Finnish municipalities. Base map Finnish Land Survey.

A special feature of Finland is the summer cottage culture, which emerged in the 1960s as a result of the late urbanization of the country. In addition to a number of rural houses having become temporary residences for the homesick city dwellers, new construction has also been vigorous. The number of holiday homes is 500 422 (Statistics Finland, 2014). Their size, quality and equipment have kept increasing constantly. In 2003, 70% of holiday homes were connected to the electrical grid and four-fifths were considered as suitable for year-round use. (Statistics Finland, 2007). The newer holiday housing differs notably from traditional rural settlements: cottages sprawl along lakeshores on vast geographical areas (Huuhka, 2012). The law regulates it in detail due to unwanted environmental and societal consequences, including sprawl, cost of municipal services, risks related to waste water management and habitat losses of wildlife and flora. However, many rural municipalities consider holiday housing as crucial for the local economy. The population of these communities may multiple during the summer holidays, often by two but even by five (Statistics Finland, 2007). In some communities, the number of holiday homes exceeds the number of permanent residences (Huuhka, 2012). Whether turning holiday homes into permanent housing should be allowed is a hardy perennial. Understanding the current magnitude of residential vacancies may provide new insight into this discussion as well.

3 Research material and methods

The methods of this study are quantitative: a geographical analysis and a descriptive statistical examination. The research material consists of three extracts from the Building and Dwelling Register (BDR), which is a part of the official Population Information System. The primary data includes all residential buildings that had vacancies in June 2014 (275 486 buildings). Non-residential buildings could not be included because their state of usage has not been recorded in the BDR since 1991. Thus, homes in the non-residential part of the building stock were also omitted. The results from the examination of vacancies were supplemented by studying demolition and replacement patterns with two data sets. The first one covers all buildings demolished in Finland in 2000–12 (50 818 buildings) and the second one consists of all buildings built to replace the demolished buildings by August 2013 (32 008 buildings).

The BDR extracts are tables that have the records on buildings as rows and tens of variables as columns. For this study, the most important variables were the coordinates; intended purpose; floor area; year of construction; primary construction material; degree of prefabrication; public subsidization and tenure type. The tables were turned into maps in the Mapinfo Professional computer programme. 16 records lacked coordinates and they were removed from the data. Thus, the raw data consists of map points with the same information as the original tables. Statistical data was formed using SQL and geographical query functions of the programme.

In the terminology of this paper, a 'building' refers to a residential building of any type and a 'home' refers to a dwelling unit, occupied or unoccupied, in a building. The buildings with vacancies belonged to three main categories and seven subcategories: three types of detached houses, two types of row houses and two types of blocks of flats. To simplify the investigation, only the primary categories were considered. Row houses and blocks of flats together are referred to as 'multi-family buildings'. As for construction materials and methods, steel buildings were considered as prefabricated and brick buildings as *in situ* built. Concrete and timber buildings with no method recorded were assumed as *in situ* built.

After consulting the literature, vacancy was considered as short-term if it did not exceed six months, mid-term if it had lasted between six months and two years, and long-term if the duration exceeded two years. Referring to the same sources, vacancy was labelled as ‘problematic’ if, in the case of multi-family buildings, at least 10% of homes had been empty for more than six months or, in the case of detached houses, the duration of vacancy exceeded two years. The number of vacancies in the data was added to the number of households in the end of 2013 (Statistics Finland, 2014), which equals the number of occupied apartments, in order to calculate vacancy rates for different building and tenure types. The research material was also complemented with official and government-maintained statistics of Finland (OSF, 2013; Suomen ympäristökeskus 2014a), which were studied for demographic change and simultaneous construction activity.

Geographical inquiries were carried out for municipalities (in 2013) and for urban and rural zones whose borders do not follow those of municipalities (see Figure 4). This is because the municipality-based division has often been considered as too rough, since municipalities are geographically large and usually encompass urban as well as rural areas (Suomen ympäristökeskus, 2014b). The borders for the former were acquired from The National Land Survey of Finland and for the latter from the Finnish Environment Institute.

3.1 Quality of the data

The BDR was compiled in 1980 with the help of questionnaires filled by erstwhile landlords. Since then, the law has bound municipal building inspection authorities to submit the information on new buildings and to update the information on existing buildings concerning such changes that have required an official permit or notification (major renovations, changes of usage or demolitions). The information on occupancies and vacancies is based on notifications of changes of addresses delivered to local register offices. It is updated twice a year (K. Kaivonen, personal communication, October 29, 2014). According to the law, residents must notify the register office if they change address permanently or temporarily (for more than three months). Only registered residents have the right to receive municipal services such as discount prices in healthcare, dental care and public transport, which is why people have a strong incentive to register in the municipality where they conduct their daily life.

A limitation of the data is that other usages are not recorded reliably in the BDR. These may include irregular residence (second homes, holiday homes) and uses as offices or other business premises. Nevertheless, the latter should not be present in significant amounts. This is because the allowed usages of buildings are defined in urban plans in a legally binding manner. Converting a building from residential to non-residential use is usually not possible without re-zoning and re-registering the intended purpose of the building. In the case of blocks of flats, urban plans may allow both residential and commercial usage, but the acceptable usage of spaces within the building is defined in the corporate articles of the blocks of flats, as they are limited liability housing companies according to the Finnish law. The corporate articles usually define dwelling as the only type of allowed usage for apartments. In all, the data set can be considered reliable, with the occurrence of irregular residence as the highest uncertainty.

As for floor area, it was necessary to bridge gaps in the raw data with estimates for 3298 buildings (1%) and 16 445 homes (1%). The missing figures were compensated using the averages of the same room number and/or building type. When available, one could also be calculated with the help of the other. Similar compensations were performed for the demolition data regarding the floor area of the buildings. All vacancy rate calculations are with the proviso that there was a six months discrepancy in the data (statistics on the whole housing stock are from the end of 2013, and the data on vacant buildings from mid-2014). Whether this would have a major effect on the vacancy rate was tested by adding the number of newly built homes from the first half of 2014 (Statistics Finland, 2014) to the whole housing stock in 2013. The resulting change of the vacancy rate was 0.06%, so the discrepancy does not seem to distort the results. In addition, it should be noted that 2.0% of the housing stock is located in non-residential buildings (Statistics Finland, 2014), and the data on vacancies does not cover these buildings although they are included in the statistics for the entire housing stock.

4 Results

4.1 Overview of vacancies

In total, the 275 486 buildings with vacancies have 1 110 267 occupied and 378 802 unoccupied homes. When no distinction is made between short-term and long-term vacancy, the phenomenon touches on 208 429 detached houses (18.5% of their stock); 23 772 row houses (30.2% of their stock); and 43 285 blocks of flats (74.1% of their stock). 163 966 buildings are completely vacant with 181 273 homes: 161 599 detached houses (14.3% of their stock, 167 623 homes), 1273 row houses (1.6% of their stock, 5 650 homes) and 1094 blocks of flats (1.9% of their stock, 8 000 homes). Table 3 shows the numbers and shares of vacant homes in the buildings of the data, and Table 4 in the whole housing stock. Table 5 compares buildings touched by vacancies with the whole building stock and makes a distinction between normal and problematic vacancy.

The gross vacancy rate in Finland is 12.7% (or 19.8% if calculated as the average of municipalities' vacancy rates). Respectively, the rate is 9.7% (16.0%) for owner-occupied housing; 10.4% (25.0%) for public-funded rental housing; and 18.2% (29.0%) for private rental housing. At smallest, the vacancy rate is 3.0% (public-funded rental housing in Helsinki; owner-occupied housing in the neighbouring city Vantaa) and at largest, 75.0% (public-funded rental housing in the rural settlement of Karijoki). Gross vacancy rates as well as vacancy rates for different tenure types show negative power correlation with population (Figures 2 and 3). Circa half of the municipalities have a gross vacancy rate greater than 20%. Compared to privately-owned housing, the vacancy rates of public housing are notably more dispersed.

	Detached houses	Row houses	Blocks of flats	Total
All homes in the data	253 329	140 443	1 085 297	1 479 069
Vacant homes	200 674	39 385	138 743	378 802
Per all homes of the building type	79.2 %	28.0 %	12.8 %	25.6 %
Short-term vacant homes	15 367	11 611	48 375	75 353
Per vacant homes of the building type	7.7%	29.5%	34.8%	19.9%
Mid-term vacant homes	21 664	9 028	31 868	62 560
Per vacant homes of the building type	10.8%	22.9%	23.0%	16.5%
Long-term vacant homes	163 643	18 746	58 500	240 889
Per vacant homes of the building type	68.1%	47.6%	42.2%	63.6%

Table 3. Number and share of vacant homes in the buildings of the data.

	Detached houses	Row houses	Blocks of flats	Total
Number of all homes	1 164 774	395 562	1 290 215	2 850 551
Overall vacancy rate	17.2 %	10.0 %	10.6 %	13.3 %
Short-term vacancy rate	1.3%	2.9%	3.7%	2.6 %
Mid-term vacancy rate	1.9%	2.3%	2.5%	2.2 %
Long-term vacancy rate	14.0%	4.7%	4.5%	8.5 %

Table 4. Share of vacant homes in the whole building stock.

	Detached houses	Row houses	Blocks of flats	Total
Number of all buildings in stock	1 128 366	78 751	58 430	1 265 547
Number of buildings with vacant homes	208 429	23 772	43 285	275 486
Per all buildings of the type in stock	18.5%	30.2%	74.1%	21.8%
Number of completely vacant buildings	161 599	1 273	1 094	163 966
Per all buildings of the type in stock	14.3%	1.6%	1.9%	13.0%
Number of buildings with normal vacancy	52 083	8 585	28 108	88 822
Per all buildings of the type in data	25.0%	36.1%	64.9%	32.2%
Number of buildings with problematic vacancy	156 346	15 137	15 177	186 664
Per all buildings of the type in data	75.0%	63.9%	35.1%	67.8%

Table 5. Number and share of buildings touched by vacancies.

The average duration of vacancy is 10.5 years for detached houses, 4.7 years for homes in row houses and 3.9 years for flats. Table 6 shows the durations of vacancies in these building types in detail. To sum up the observations from Tables 3–6, most vacant homes are detached houses, and over two-thirds of them are long-term vacant. Although there are significant numbers of empty homes in blocks of flats as well, these are more often short-term vacant and in two-thirds of the buildings, the vacancy is to be considered as normal transaction vacancy. Figure 4 shows how the whole housing stock and vacant homes are distributed to geographical areas of different degree of urbanization. In cities, the share of vacant homes is smaller than the share of all homes, and in the countryside, the situation is the opposite.

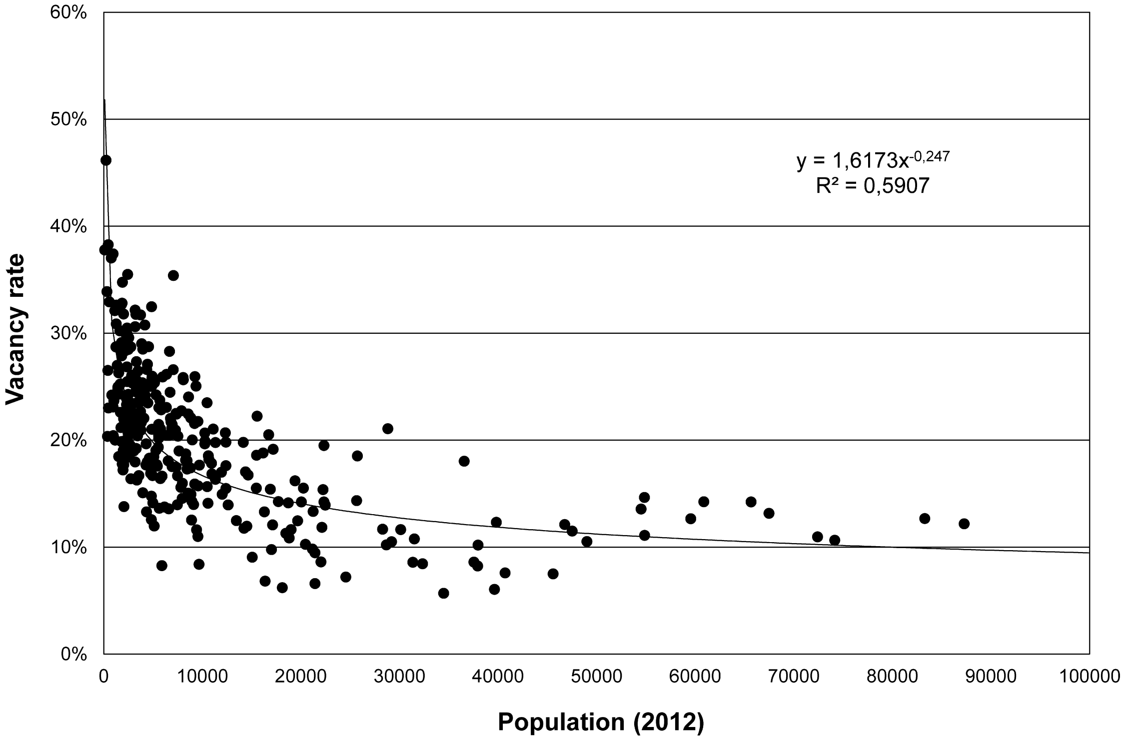

Figure 2. Gross vacancy rates and populations of Finnish municipalities. Note: The figure has been cropped to exclude nine cities with over 100 000 inhabitants for better readability.

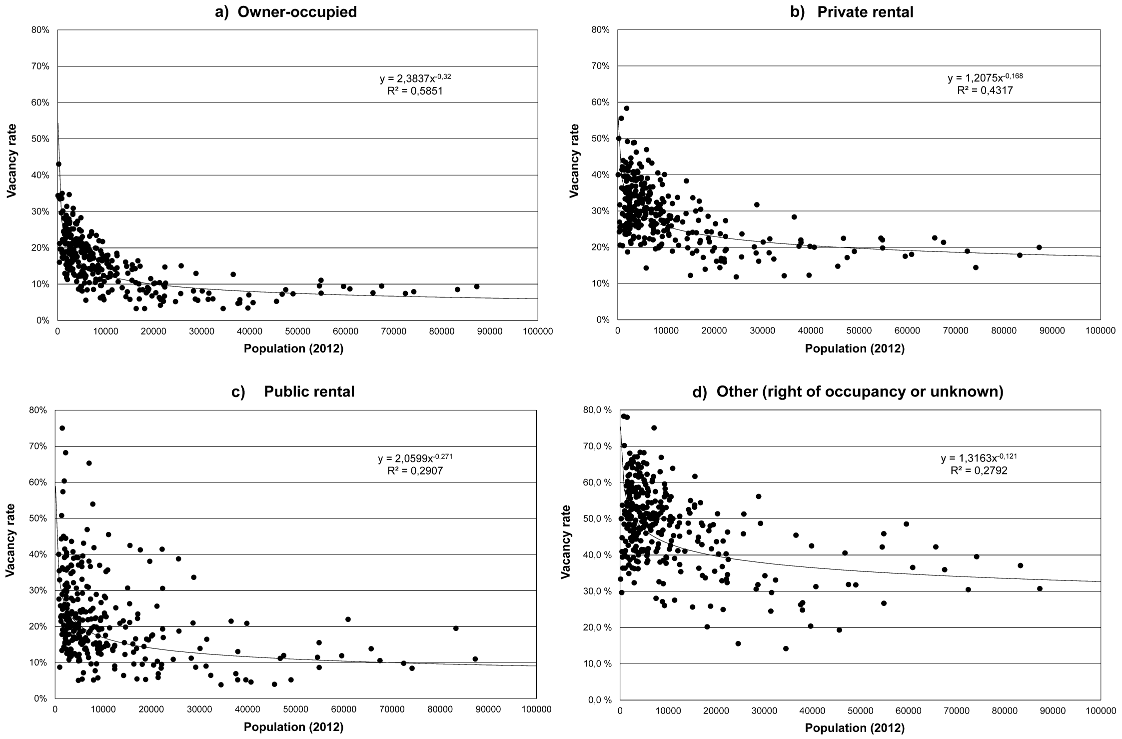

Figure 3. Vacancy rates for different tenure types and populations of Finnish municipalities: a) owner-occupied housing; b) private rental housing; c) public rental housing d) other (right of occupancy and unknown). Notes: In the whole housing stocks of municipalities, the shares of the tenure types are as follows (average [min, max]): owner-occupied 73% [46; 90]; private rental 13% [5; 44]; public rental 8% [1; 20]; other 6% [3; 20]. The figure has been cropped to exclude nine cities with over 100 000 inhabitants for better readability. Clearly erroneous figures (*i.e.* 0% and 100%) have been removed from the figure. These include public housing in Åland Islands (16 municipalities) due to data missing from the official statistics.

Duration of vacancy	**Homes in detached houses**	**Homes in row houses**	**Homes in blocks of flats**	**Total**
1 year or less	23 403 (11.7%)	15 862 (40.3%)	63 873 (46.0%)	103 138 (27.2%)
1-2 years	13 179 (6.6%)	4 892 (12.4%)	17 153 (12.4%)	35 224 (9.3%)
Short to mid-term, total	**36 582 (18.2%)**	**20 754 (52.7%)**	**81 026 (58.4%)**	**138 362 (36.5%)**
2-5 years	29 768 (14.8%)	6 723 (17.1%)	22 736 (16.4%)	59 227 (15.6%)
5-10 years	40 507 (20.2%)	5 298 (13.5%)	16 843 (12.1%)	62 648 (16.5%)
10-20 years	62 330 (31.1%)	4 778 (12.1%)	13 504 (9.7%)	80 612 (21.3%)
20-30 years	31 112 (15.5%)	1 814 (4.6%)	4 455 (3.2%)	37 381 (9.9%)
over 30 years	375 (0.2%)	18 (0.0%)	174 (0.1%)	567 (0.1%)
Long-term, total	**164 092 (81.8%)**	**18 631 (47.3%)**	**57 712 (41.6%)**	**240 435 (63.5%)**

Table 6. Duration of vacancy in different building types.

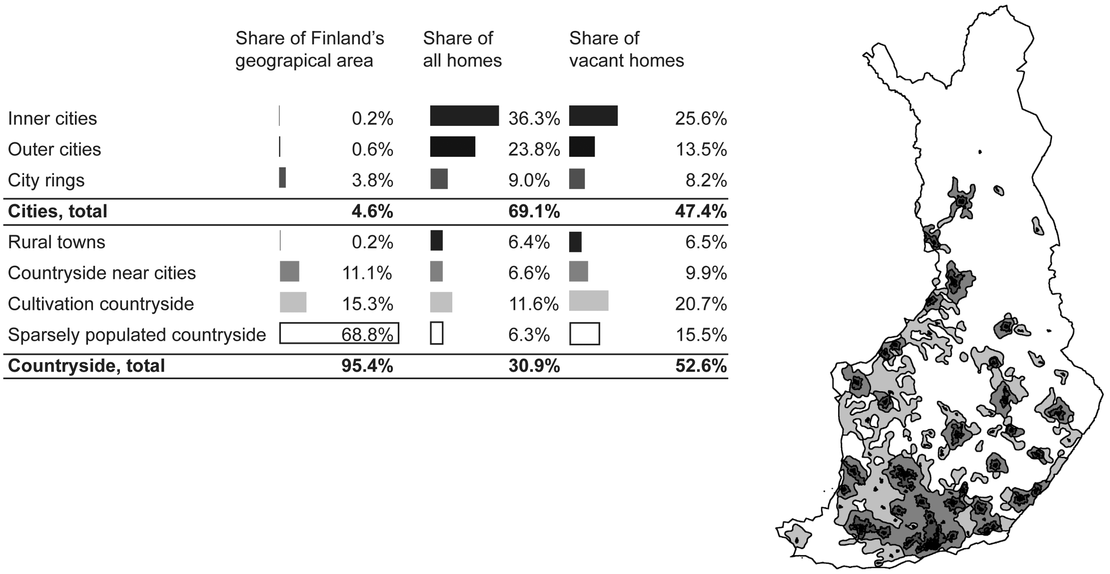

Figure 4. Location of vacant homes. Shares of all homes were calculated with 2012 data (Suomen ympäristökeskus, 2014a). Base map Finnish Land Survey.

4.2 Properties of buildings with problematic vacancies

In this section, the paper zooms to that part of the vacant stock that has problematic vacancies and examines the properties of these buildings in comparison to buildings with normal vacancies and the whole building stock. Table 7 presents the areas of the buildings. Although there are far more problematically vacant homes in detached houses, there is slightly more floor area in blocks of flats with problematic vacancies. Although this area includes both vacant and occupied flats, the future of the whole buildings can be seen as being at risk. As seen in Figures 5, 6 and 7, the share of problematic vacancies is higher in the older cohorts, but the largest numbers occur in buildings of different age depending on the building type: in older detached houses (–1960), contemporary row houses (1970–2000) and post-war blocks of flats (1940–1980). Figure 8 shows that vacant homes concentrate on private ownership in all building and tenure types. Detached houses are more prevalent amongst buildings with problematic vacancies than amongst buildings with normal vacancies.

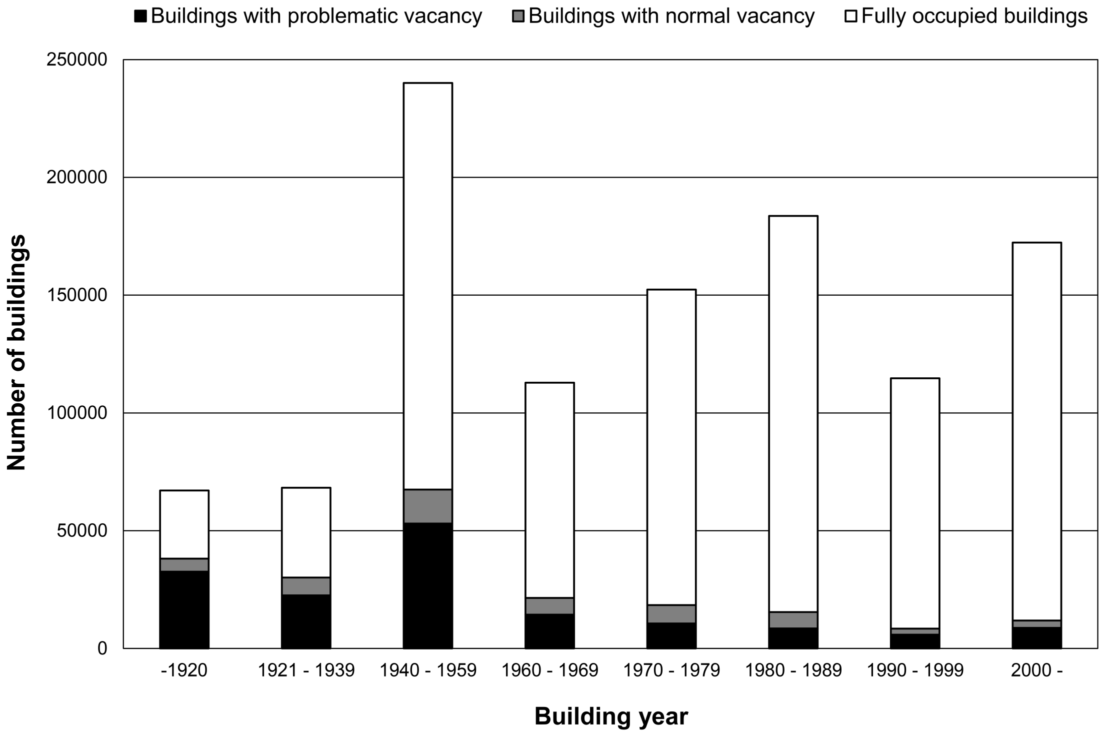

Figure 5. Building year distribution of detached houses.

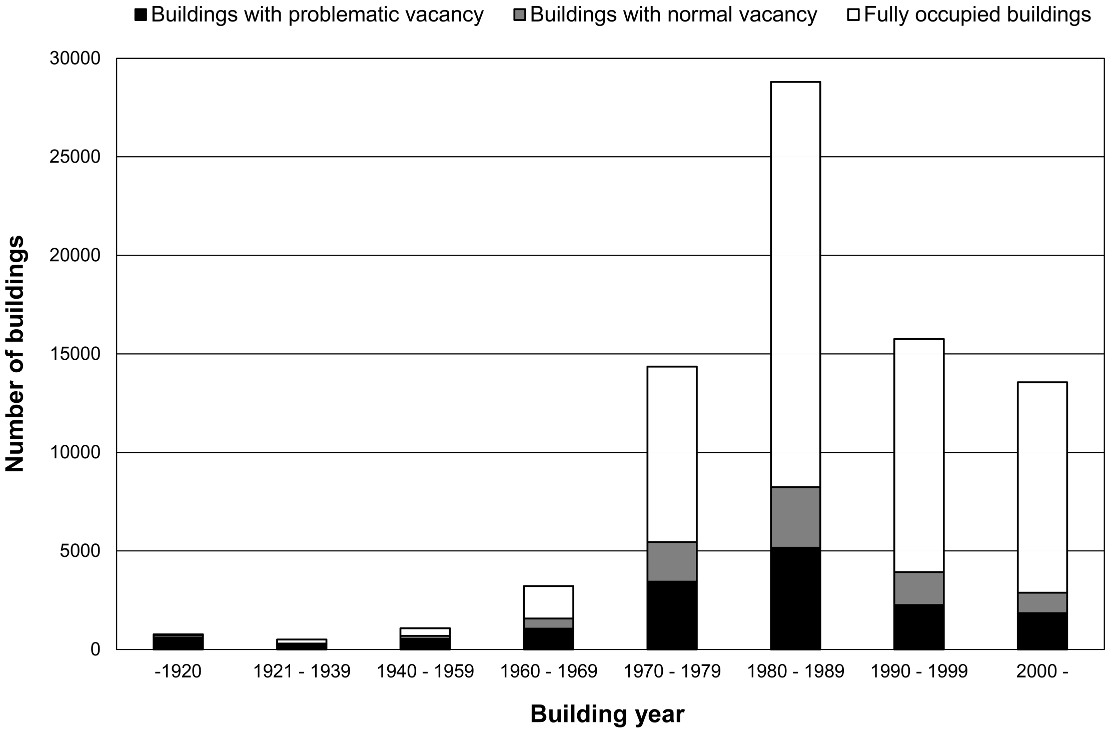

Figure 6. Building year distribution of row houses.

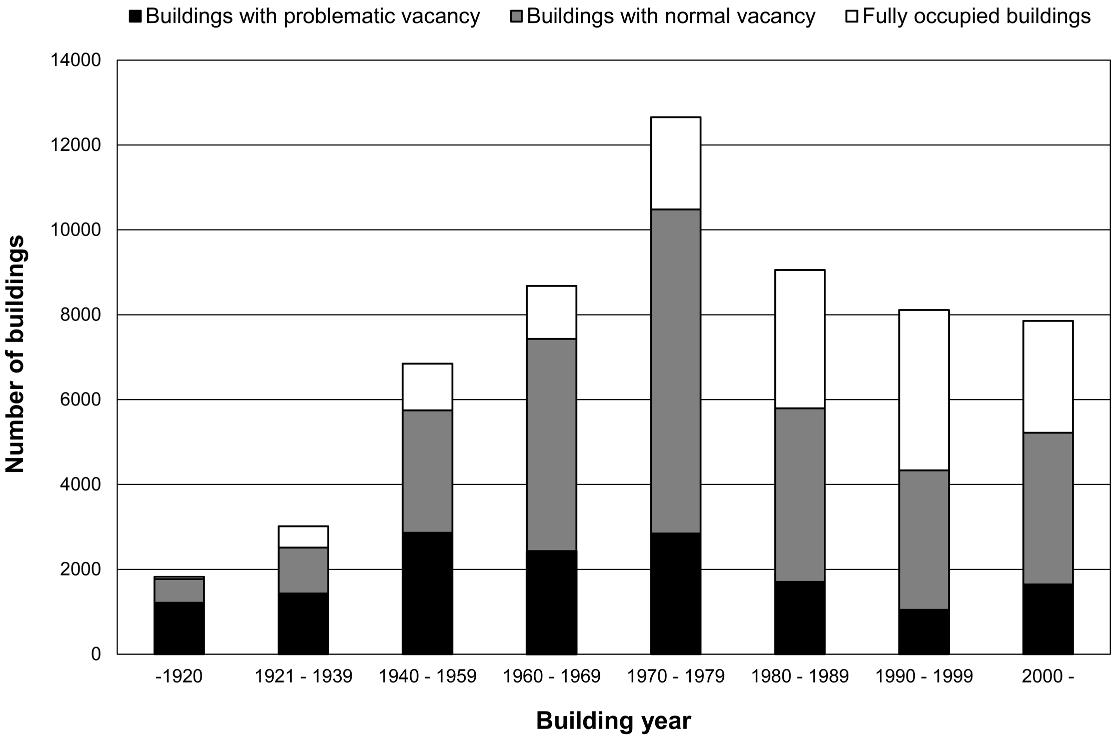

Figure 7. Building year distribution of blocks of flats.

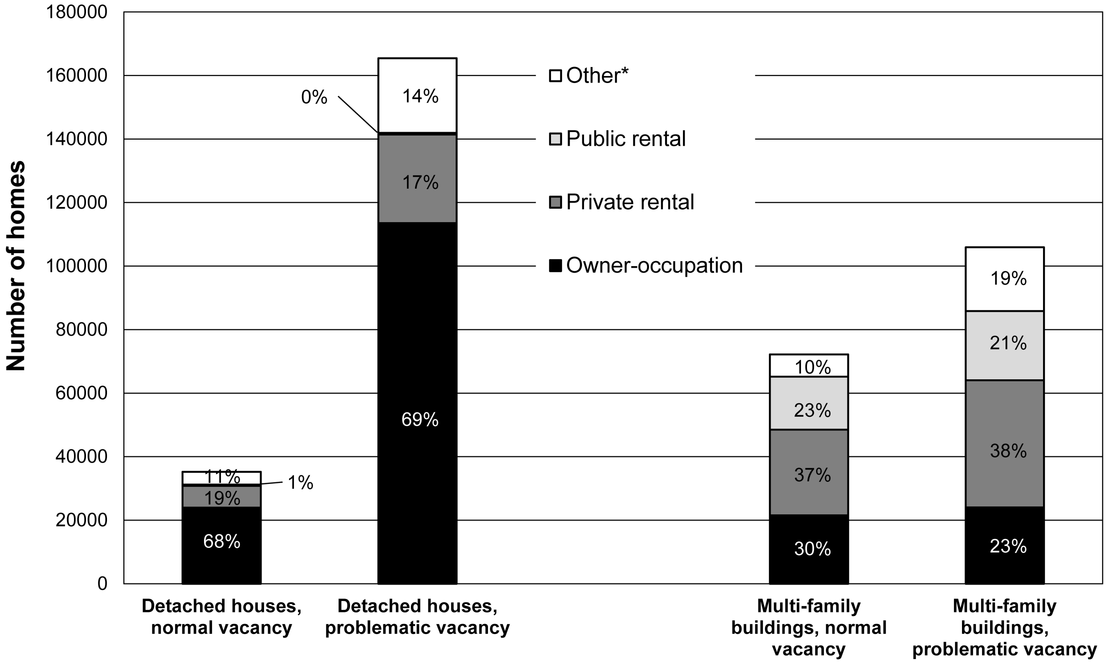

Figure 8. Numbers of normally and problematically vacant homes with different building and tenure types. * Other tenure types include right of occupancy and unknown tenure.

Tables 8 and 9 present the construction materials and methods of buildings with problematic vacancies. Detached houses and row houses are mostly wooden, while blocks of flats are usually made of *in situ* cast concrete. Due to the significant size differences between the different building types, the floor area (Table 9) gives a better indication of the volumes of embedded materials than the number of buildings (Table 8). Timber is the prevalent material, followed by *in situ* cast concrete. The share of prefabricated concrete is equal to that of bricks; the proportion of steel is negligible. In all, 14.4% of the floor area is prefabricated: 10.6% is made of prefabricated concrete and 3.6% of prefabricated timber. However, it is highly likely that a significant share of *in situ* cast concrete buildings have prefabricated facades. According to Neuvonen (2006, p.150), *in situ* cast floors and prefabricated facades was the most common construction method in 1960–75. Alas, the data does not recognize partially prefabricated buildings.

	Detached houses	**Row houses**	**Blocks of flats**	**Total**
Area of all buildings in stock	158 054 032	33 537 646	93 825 473	285 417 151
Area of buildings with vacant homes	20 851 302	8 817 382	60 777 208	90 445 892
Area of buildings with problematic vacancy	14 706 794	5 323 675	15 146 911	35 177 380
Per all area of the building type in stock	9.3%	15.9%	16.1%	12.3%
Per all area of the building type in data (buildings with vacancies)	70.5%	60.4%	24.9%	38.9%
Area of completely vacant buildings	10 352 982	323 144	423 511	11 099 637
Per all area of the building type with problematic vacancies	70.4%	6.1%	2.8%	31.6%

Table 7. Area and share of buildings touched by normal and problematic vacancy and completely empty 8uildings.

	Detached houses	**Row houses**	**Blocks of flats**	**Total**
Concrete, prefabricated	380 (0.2%)	604 (4.0%)	2 586 (17.0%)	3 570 (2.0%)
Concrete, in situ cast	2 143 (1.4%)	1 527 (10.1%)	6 582 (43.4%)	10 252 (5.6%)
Bricks, built in place	3 804 (2.5%)	1 072 (7.1%)	2 284 (15.0%)	7 160 (3.9%)
Steel, prefabricated	118 (0.1%)	23 (0.2%)	36 (0.2%)	177 (0.1%)
Wood, prefabricated	6 091 (4.0%)	1 288 (8.5%)	62 (0.4%)	7 441 (4.1%)
Wood, built in place	139 993 (91.8%)	10 470 (69.2%)	3 481 (22.9%)	153 944 (84.2%)
Other	0 (0.0%)	39 (0.3%)	43 (0.3%)	82 (0.0%)
Material unknown	0 (0.0%)	115 (0.8%)	103 (0.7%)	218 (0.1%)
All	152 529 (100.0%)	15 138 (100.0%)	15 177 (100.0%)	182 844 (100.0%)

Table 8. Number of buildings with problematic vacancy from different construction materials.

	Detached houses	Row houses	Blocks of flats	Total
Concrete, prefabricated	70 554 (0.5%)	260 359 (4.9%)	3 350 168 (22.1%)	3 681 081 (10.6%)
Concrete, in situ cast	343 785 (2.4%)	732 856 (13.8%)	7 783 112 (51.4%)	8 859 753 (25.4%)
Bricks, built in place	585 265 (4.1%)	459 069 (8.6%)	2 738 076 (18.1%)	3 782 410 (10.6%)
Steel, prefabricated	16 769 (0.1%)	8 363 (0.2%)	46 634 (0.3%)	71 766 (0.2%)
Wood, prefabricated	810 199 (5.6%)	423 562 (8.0%)	35 956 (0.2%)	1 269 717 (3.6%)
Wood, built in place	12 560 299 (87.3%)	3 386 351 (63.6%)	1 053 773 (7.0%)	17 000 423 (48.8%)
Other	0 (0.0%)	15 312 (0.3%)	48 726 (0.3%)	64 038 (0.2%)
Material unknown	0 (0.0%)	37 776 (0.7%)	90 468 (0.6%)	128 244 (0.4%)
All	14 386 871 (100.0%)	5 323 648 (100.0%)	15 146 913 (100.0%)	34 857 432 (100.0%)

Table 9. Area of buildings with problematic vacancy from different construction materials.

As seen in Tables 10 and 11, which cover all residential building types, the proportion of problematic vacancy is the higher the more rural the area. Similarly, the share of completely empty buildings or floor area is the higher the more peripheral the location. Tables 12 and 13 present the same information for detached houses, Tables 14 and 15 for row houses and Tables 16 and 17 for blocks of flats. Comparing the tables shows that only blocks of flats in all sub-areas of cities and row houses in outer cities have more normal vacancies than problematic vacancies. As can be expected, in multi-family buildings, the share of completely empty buildings is relatively low even in the most distressed areas. However, even in cities, every second row house and over 40% of blocks of flats that have empty homes are challenged by problematic vacancies. Nevertheless, problematic vacancies hit detached houses the hardest. The majority of problematically vacant detached houses and row houses are spread across the vast countryside, while most blocks of flats are situated in cities and, more specifically, in city centres. Looking at floor areas, blocks of flats in cities contain the most floor space (of the buildings with problematic vacancies). Although the amount of floor area is nearly as large in rural detached houses, these buildings are scattered on regions that encompass, as Figure 4 shows, over 95% of Finland's geographical area. Cities, where the blocks of flats are located, cover only 5%.

Geographical area	**Buildings with normal vacancy**	**Buildings with problematic vacancy**	**Completely empty buildings**	**Completely empty buildings per buildings with problematic vacancy**
Inner cities	24 610 (60.2%)	16 291 (39.8%)	3 522	21.6%
Outer cities	18 629 (51.7%)	17 373 (48.2%)	7 377	42.5%
City rings	8 519 (31.7%)	18 358 (68.3%)	13 682	74.5%
Cities, total	**51 758 (49.9%)**	**52 022 (50.1%)**	**24 581**	**47.3%**
Rural towns	5 835 (38.1%)	9 455 (61.8%)	4 466	47.2%
Countryside near cities	7 762 (22.2%)	27 147 (77.8%)	22 218	81.8%
Cultivation countryside	14 816 (21.7%)	53 386 (78.3%)	43 219	81.0%
Sparsely populated countryside	8 653 (16.2%)	44 652 (83.8%)	39 863	89.3%
Countryside, total	**37 066 (21.6%)**	**134 640 (78.4%)**	**109 766**	**81.5%**

Table 10. Number of buildings. Problematically vacant buildings include completely empty buildings.

Geographical area	**Buildings with normal vacancy**	**Buildings with problematic vacancy**	**Completely empty buildings**	**Completely empty buildings per buildings with problematic vacancy**
Inner cities	34 071 869 (76.6%)	10 409 100 (23.4%)	489 087	4.7%
Outer cities	11 904 164 (71.3%)	4 783 438 (28.7%)	730 249	15.3%
City rings	2 156 197 (43.7%)	2 777 086 (56.3%)	1 193 236	43.0%
Cities, total	**48 132 230 (72.8%)**	**17 969 624 (27.2%)**	**2 412 572**	**13.4%**
Rural towns	2 408 894 (44.7%)	2 985 534 (55.3%)	433 295	14.5%
Countryside near cities	1 191 224 (27.7%)	3 102 077 (72.3%)	1 837 309	59.2%
Cultivation countryside	2 437 490 (26.6%)	6 725 790 (73.4%)	3 427 760	51.0%
Sparsely populated countryside	1 099 050 (20.0%)	4 394 128 (80.0%)	2 988 656	68.0%
Countryside, total	**7 136 658 (29.3%)**	**17 207 529 (70.7%)**	**8 687 020**	**50.5%**

Table 11. Area of buildings. Problematically vacant buildings include long-term completely empty buildings.

Geographical area	Detached houses with normal vacancy	Detached houses with problematic vacancy	Completely empty detached houses	Completely empty detached houses per detached houses with problematic vacancy
Inner cities	5 139 (39.5%)	7 861 (60.5%)	3 149	40.1%
Outer cities	9 311 (43.0%)	12 355 (57.0%)	7 112	57.6%
City rings	6 811 (29.4%)	16 327 (70.6%)	13 469	82.5%
Cities, total	**21 261 (36.8%)**	**36 543 (63.2%)**	**23 730**	**64.9%**
Rural towns	3 483 (38.0%)	5 687 (62.0%)	4 229	74.4%
Countryside near cities	6 880 (21.6%)	25 040 (78.4%)	22 575	90.2%
Cultivation countryside	12 597 (21.0%)	47 356 (79.0%)	42 652	90.1%
Sparsely populated countryside	7 860 (15.9%)	41 721 (84.1%)	39 439	94.5%
Countryside, total	**30 820 (25.7%)**	**119 804 (74.3%)**	**108 895**	**90.9%**

Table 12. Number of detached houses. Problematically vacant buildings include long-term completely empty buildings.

Geographical area	Detached houses with normal vacancy	Detached houses with problematic vacancy	Completely empty detached houses	Completely empty detached houses per detached houses with problematic vacancy
Inner cities	785 364 (40.3%)	1 164 398 (59.7%)	317 095	27.2%
Outer cities	1 224 472 (44.5%)	1 527 094 (55.6%)	628 156	41.1%
City rings	821 745 (33.0%)	1 665 363 (67.0%)	1 127 077	67.7%
Cities, total	**2 831 581 (39.4%)**	**4 356 855 (60.6%)**	**2 072 328**	**47.6%**
Rural towns	425 130 (40.3%)	629 398 (59.7%)	367 115	58.3%
Countryside near cities	755 645 (25.1%)	2 260 658 (74.9%)	1 775 175	78.5%
Cultivation countryside	1 362 896 (24.7%)	4 159 428 (75.3%)	3 263 383	78.5%
Sparsely populated countryside	769 355 (18.9%)	3 300 228 (81.1%)	2 874 936	87.1%
Countryside, total	**3 313 026 (24.2%)**	**10 349 712 (75.8%)**	**8 280 609**	**80.0%**

Table 13. Area of detached houses. Problematically vacant buildings include completely empty buildings.

Geographical area	Row houses with normal vacancy	Row houses with problematic vacancy	Completely empty row houses	Completely empty row houses per row houses with problematic vacancy
Inner cities	1 470 (48.2%)	1 578 (51.8%)		7.0%
Outer cities	2 692 (51.4%)	2 546 (48.6%)	121	4.8%
City rings	849 (40.8%)	1 231 (59.2%)	119	9.7%
Cities, total	**5 011 (48.3%)**	**5 355 (51.7%)**	**350**	**6.5%**
Rural towns	804 (33.1%)	1 622 (66.9%)	112	6.9%
Countryside near cities	634 (29.1%)	1 547 (70.9%)	142	9.2%
Cultivation countryside	1 571 (26.7%)	4 307 (73.3%)	331	7.7%
Sparsely populated countryside	615 (21.0%)	2 307 (79.0%)	306	13.3%
Countryside, total	**3 624 (27.0%)**	**9 783 (73.0%)**	**891**	**9.1%**

Table 14. Number of row houses. Problematically vacant buildings include completely empty buildings.

Geographical area	Row houses with normal vacancy	Row houses with problematic vacancy	Completely empty row houses	Completely empty row houses per row houses with problematic vacancy
Inner cities	754 286 (52.6%)	680 382 (47.4%)	29 995	4.4%
Outer cities	1 176 078 (46.3%)	1 013 333 (46.3%)	35 094	3.5%
City rings	333 700 (42.9%)	443 913 (57.1%)	34 689	7.8%
Cities, total	**2 264 064 (51.4%)**	**2 137 628 (48.6%)**	**99 778**	**4.7%**
Rural towns	298 659 (34.2%)	574 330 (65.8%)	27 445	4.8%
Countryside near cities	211 047 (29.5%)	504 593 (70.5%)	34 589	6.9%
Cultivation countryside	531 603 (27.3%)	1 414 418 (72.7%)	86 202	6.1%
Sparsely populated countryside	188 611 (21.4%)	692 706 (78.6%)	75 130	10.8%
Countryside, total	**1 229 920 (27.9%)**	**3 186 047 (72.1%)**	**223 366**	**7.0%**

Table 15. Area of row houses. Problematically vacant buildings include completely empty buildings.

Geographical area	**With normal vacancy**	**With problematic vacancy**	**Completely empty blocks of flats**	**Completely empty blocks of flats per blocks of flats with problematic vacancy**
Inner cities	18 001 (72.4%)	6 852 (27.6%)		3.8%
Outer cities	6 626 (72.8%)	2 472 (27.2%)	144	5.8%
City rings	859 (51.8%)	800 (48.2%)	94	11.8%
Cities, total	**24 486 (58.7%)**	**10 124 (41.3%)**	**501**	**4.9%**
Rural towns	1 548 (41.9%)	2 146 (58.1%)	125	5.8%
Countryside near cities	248 (30.7%)	560 (69.3%)	98	17.5%
Cultivation countryside	648 (27.3%)	1 723 (72.7%)	236	13.7%
Sparsely populated countryside	178 (22.2%)	624 (77.8%)	118	18.9%
Countryside, total	**2 622 (34.2%)**	**5 053 (65.8%)**	**577**	**11.4%**

Table 16. Number of blocks of flats. Problematically vacant buildings include completely empty buildings.

Geographical area	**With normal vacancy**	**With problematic vacancy**	**Completely empty blocks of flats**	**Completely empty blocks of flats per blocks of flats with problematic vacancy**
Inner cities	32 532 219 (79.2%)	8 564 320 (20.8%)	141 997	1.7%
Outer cities	9 503 614 (80.9%)	2 243 011 (19.1%)	66 999	3.0%
City rings	1 000 752 (60.0%)	667 810 (40.0%)	31 470	4.7%
Cities, total	**43 036 585 (78.9%)**	**11 475 141 (21.1%)**	**240 466**	**2.1%**
Rural towns	1 685 105 (48.6%)	1 781 806 (51.4%)	38 735	2.2%
Countryside near cities	224 532 (40.0%)	336 826 (60.0%)	27 545	8.2%
Cultivation countryside	542 991 (32.0%)	1 151 944 (68.0%)	78 175	6.8%
Sparsely populated countryside	141 084 (26.0%)	401 194 (74.0%)	38 590	9.6%
Countryside, total	**2 593 712 (41.4%)**	**3 671 770 (58.6%)**	**183 045**	**5.0%**

Table 17. Area of blocks of flats. Problematically vacant buildings include completely empty buildings.

4.3 Comparison to new construction and demolition

This section compares the number of vacant homes and area of problematically vacant buildings to those of new construction and demolition to reveal the magnitude of the reserves in the underutilized housing stock. Table 18 shows that in mid-2014, circa 8.5 times as many homes were long-term vacant as were built in the previous year or as were demolished during 13 years (2000–12). Compared to the current pace of new construction, the vacant stock is especially large for detached houses: over 17 times the yearly production. For blocks of flats, it is roughly four times the yearly addition. On the other hand, flats' vacant stock is notable with regard to demolition: nearly 12 times as many homes are long-term vacant in blocks of flats as have been demolished from blocks of flats in over a decade. In other words, at the past demolition pace, it would take over 100 years to demolish the long-term vacant homes from blocks of flats.

	Detached houses	**Row houses**	**Blocks of flats**	**Total (incl. homes in NRB)**
New homes in 2013	9 559	3 705	15 242	28 506
Demolished homes 2000-2012	18 002	2 364	4 930	28 158
Long-term vacant homes	163 643	18 746	58 500	240 889
Per new homes	1712%	506%	384%	845%
Per demolished homes	909%	793%	1187%	855%

Table 18. Number of long-term vacant homes compared to the number of new homes built in 2013 and demolished between 2000 and 2012.

When looking at the floor areas of buildings (Table 19), the magnitudes of the underutilized stocks in multi-family buildings come off larger than if only vacant homes are observed. This is natural because although these are buildings at risk, they keep containing many occupied homes. When compared to the past magnitude of demolition, the stocks at risk encompass significant amounts of floor space: in blocks of flats, for instance, more than 58 times as much as was demolished between 2000–12.

	Detached houses	**Row houses**	**Blocks of flats**	**Total**
Area of newly constructed buildings in 2013	1 774 842	341 660	1 221 264	3 337 766
Area of demolished buildings 2000-2012	1 448 106	147 611	260 700	1 856 417
Area of problematically vacant buildings	14 706 794	5 323 675	15 146 911	35 177 380
Per area of new buildings	829%	1558%	1240%	1054%
Per area of demolished buildings	1016%	3607%	5810%	1894%

Table 19. Area of problematically vacant buildings compared to the area of new residential buildings built in 2013 and demolished between 2000 and 2012.

4.4 Vacancy patterns

This part of the examination focuses on calculating linear correlations for vacancy, demolition and other variables in the scale of municipalities. Although the number of vacant homes correlates strongly with the population of the community (r=0.96, Figure 9) and the size of the housing stock (r=0.97), the correlations are negative for the vacancy rate (r=-0.40 and r=-0.38 in a respective order). Figures 2 and 3 show that the negative correlation with population is, in fact, power correlation. The situation is similar with the change of inhabitants (in absolute numbers): the correlation is positive with the number of empty homes (r=0.78) but negative with the proportion of empty homes (r=-0.39). Unsurprisingly, the correlation between the vacancy rate and the relative change of population is clearly negative (r=-0.73, Figure 10). As could be expected, the share of long-term vacant homes is the greater the higher the vacancy rate is (r=0.79, Figure 11). In addition, the share of vacant homes has a strong positive correlation with the share of over 65-year-old population (r=0.76, Figure 12). Here, it must be noted that the number of inhabitants and the share of over 65 year-olds correlates negatively (r=-0.30), suggesting that the share is usually higher in smaller communities. In brief: the larger the community, the larger the net migration (absolute as well as relative), and the larger the number of empty homes, but the smaller the vacancy rate. In addition, the smaller the vacancy rate, the smaller the share of the elderly and long-term vacant homes.

To study the connection between demolition and vacancy, correlations were calculated for the current vacancy rate; the floor area demolished between 2000–12; and the number of demolished homes. The correlations are negative (r=-0.36 and r=-0.45 in a respective order), which suggest that the higher the vacancy rate, the less was demolished in absolute numbers (see Figure 13). This is explained by the sizes of the municipalities: the ones with high vacancy rates are small and have small housing stocks. Practically no linear correlation, however, occurred (r=0.02) between the share of demolished homes and the vacancy rate (Figure 14).

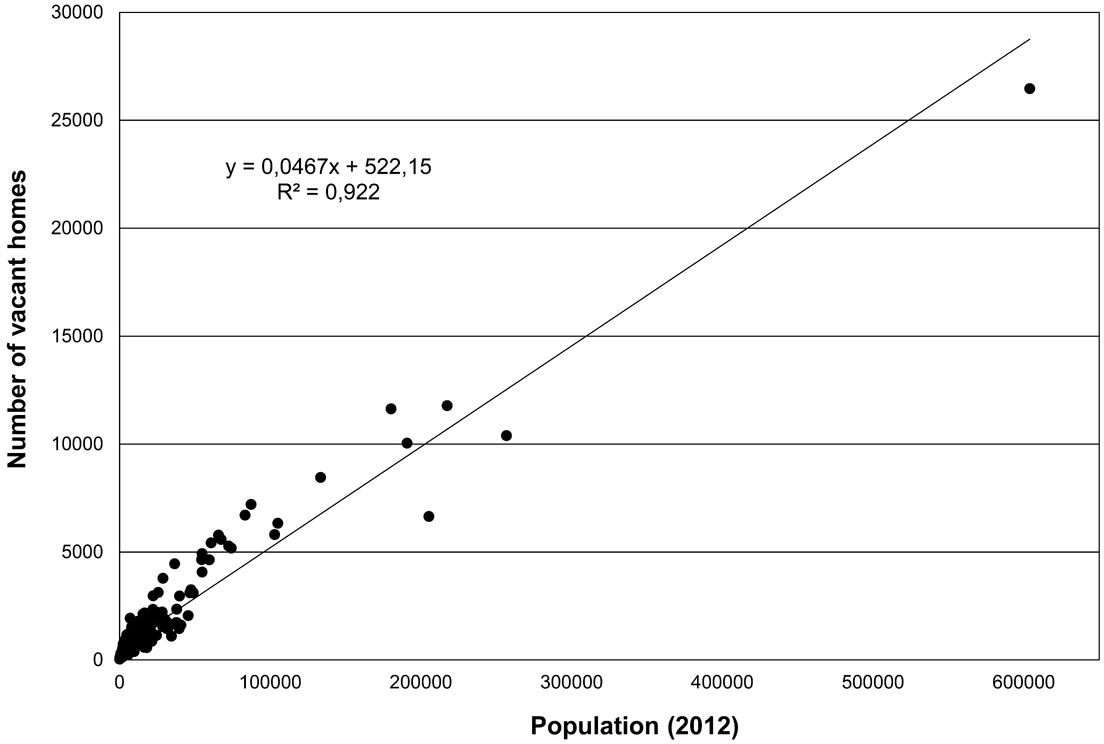

Figure 9. Numbers of vacant homes and populations of Finnish municipalities.

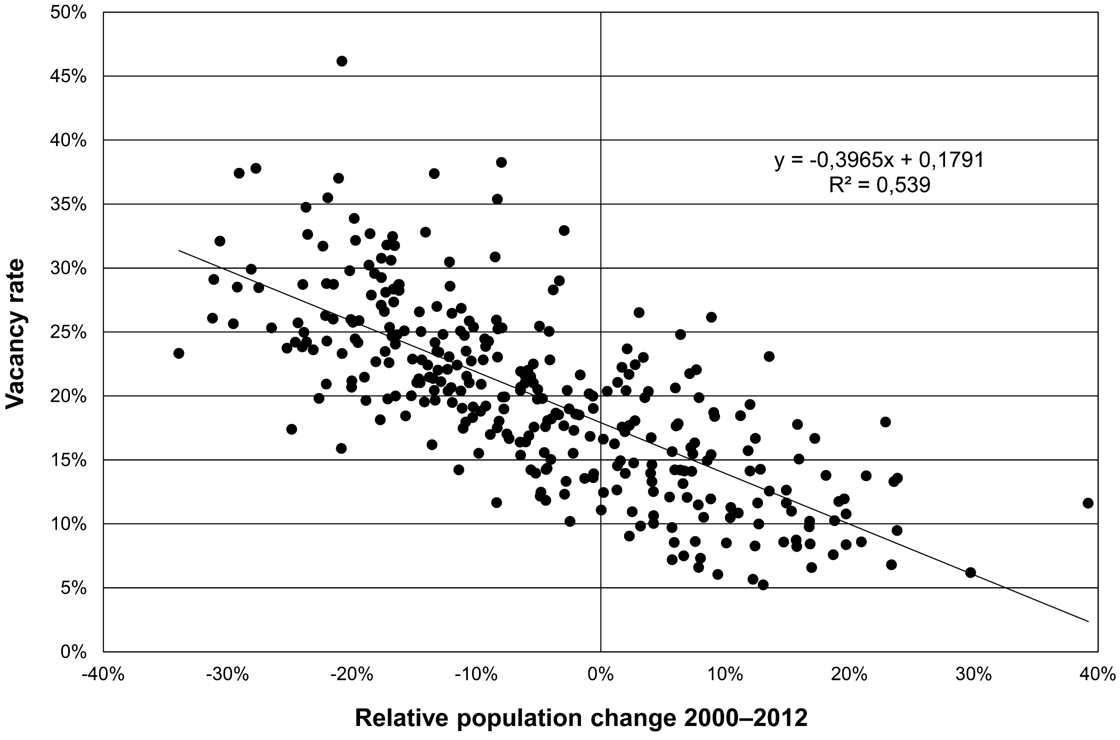

Figure 10. Vacancy rates and relative population changes in Finnish municipalities.

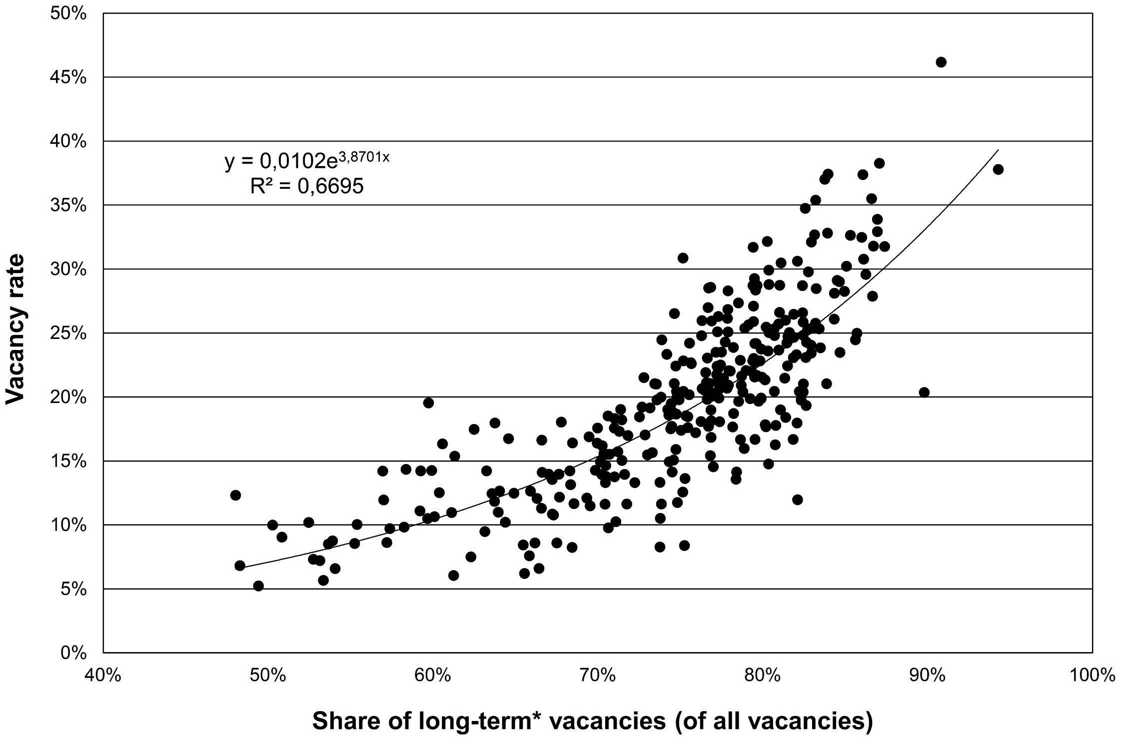

Figure 11. Vacancy rates and shares of long-term* vacancies of all vacancies in Finnish municipalities. * In this chart only: homes that have been vacant for more than 18 months regardless of the building type.

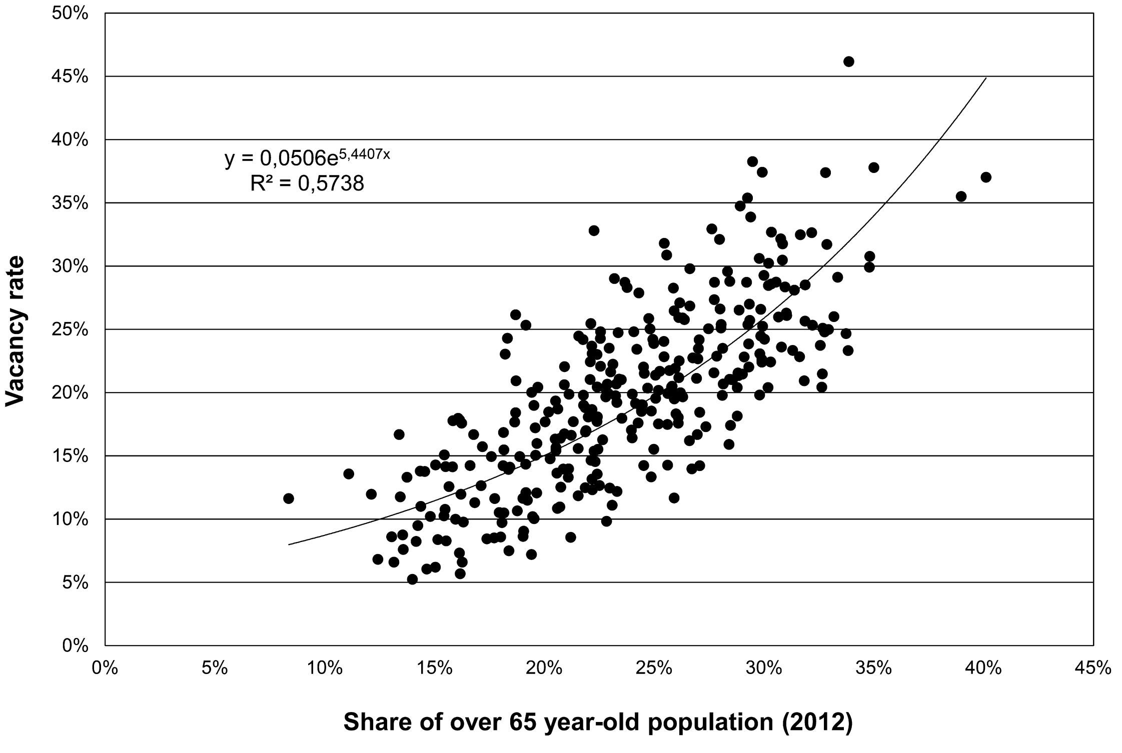

Figure 12. Vacancy rates and shares of over 65 year-olds in Finnish municipalities.

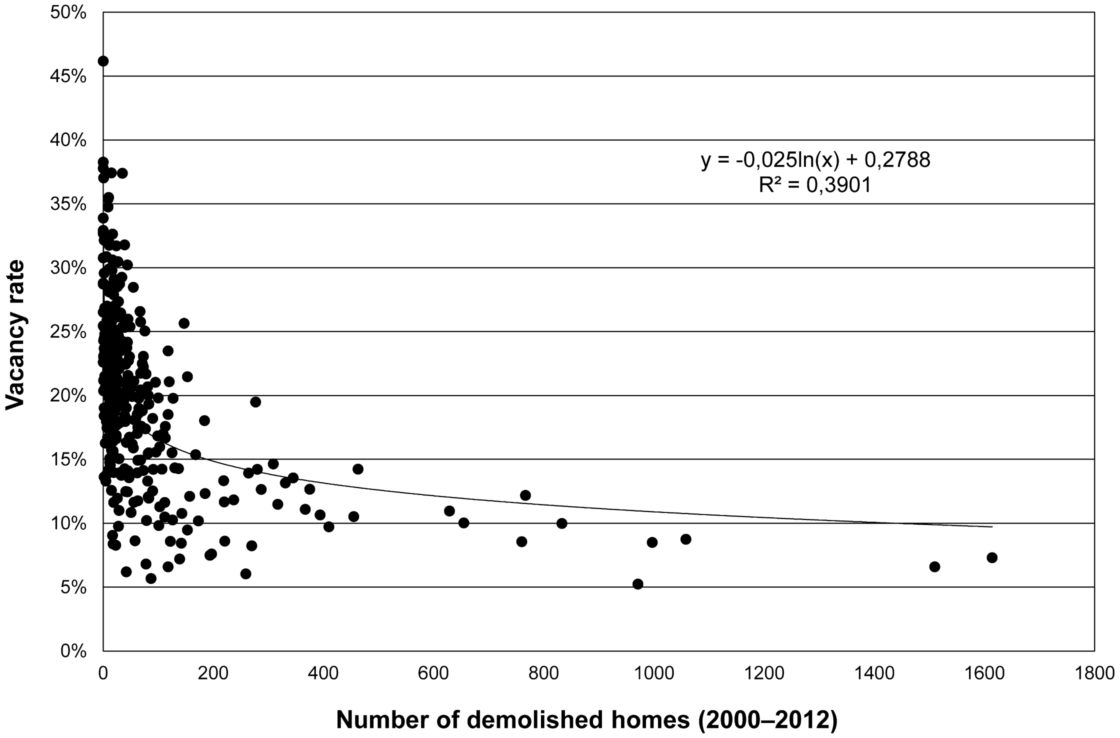

Figure 13. Vacancy rates and numbers of demolished homes in Finnish municipalities.

Figure 14. Vacancy rates and demolition rates in Finnish municipalities.

4.5 Replacement behaviour

To consider possible futures for vacant buildings, replacement behaviour of buildings was studied by comparing demolished and built buildings on the same plots. In total, 10 520 pieces of real estate had residential buildings demolished and new buildings built in 2000–12. In 81% of them, new construction was residential. As Table 20 shows, detached houses were usually substituted with detached houses and blocks of flats with blocks of flats. Row houses, however, were most often replaced with non-residential buildings. Tables 21, 22, and 23 zoom on the replacement behaviour in urban and rural area types. Regardless of the degree of urbanity, detached houses were most often replaced with detached houses. Exchange into non-residential buildings was notable in the countryside. Row houses were usually exchanged into blocks of flats in inner cities; more often into blocks of flats or detached houses than row houses in outer cities; and usually into detached houses in city rings. Replacing old row houses with row houses was common only in the countryside. However, the majority of row houses in all area types, except inner cities and sparsely populated countryside, were exchanged into non-residential buildings. Replacing blocks of flats with the same type prevailed only in inner cities and rural towns, *i.e.* community centres. In outer cities, blocks of flats usually made way for detached houses, and in all other area types, for non-residential buildings.

Demolished building	**New construction**					
	None	**Detached house**	**Row house**	**Block of flats**	**NRB**	**Total**
Detached house	51.9%	33.4%	3.3%	2.7%	8.8%	100%
Row house	51.7%	4.8%	7.3%	11.9%	24.2%	100%
Block of flats	57.1%	9.9%	2.6%	17.8%	12.5%	100%

Table 20. New construction on the plots of demolished residential buildings. NRB=non-residential building.

Geographical area	**None**	**Detached house**	**Row house**	**Block of flats**	**NRB**
Inner cities	39.0%	38.8%	7.6%	8.5%	6.0%
Outer cities	47.6%	40.2%	3.7%	1.2%	7.2%
City rings	54.2%	35.7%	1.2%	1.1%	7.8%
Rural towns	61.1%	21.2%	3.6%	4.2%	10.0%
Countryside near cities	57.8%	19.5%	0.7%	0.4%	11.6%
Cultivation countryside	60.8%	26.0%	1.6%	0.6%	10.9%
Sparsely populated countryside	80.8%	10.5%	0.2%	0.1%	8.3%

Table 21. New construction on the plots of demolished detached houses.

Geographical area	None	Detached house	Row house	Block of flats	NRB
Inner cities	44.3%	6.1%	6.9%	34.4%	8.4%
Outer cities	30.9%	8.7%	7.4%	9.4%	43.6%
City rings	77.8%	5.6%	3.7%	1.9%	11.1%
Rural towns	53.3%	0.0%	2.2%	0.0%	44.4%
Countryside near cities	53.6%	1.8%	10.7%	3.6%	30.4%
Cultivation countryside	73.2%	1.2%	7.3%	1.2%	17.1%
Sparsely populated countryside	74.4%	2.7%	15.4%	0.0%	7.7%

Table 22. New construction on the plots of demolished row houses.

Geographical area	None	Detached house	Row house	Block of flats	NRB
Inner cities	47.0%	11.0%	3.6%	29.0%	9.4%
Outer cities	67.7%	15.3%	1.6%	3.2%	12.1%
City rings	67.5%	5.0%	5.0%	7.5%	15.0%
Rural towns	69.6%	8.9%	1.8%	10.7%	8.9%
Countryside near cities	67.3%	0	0	9.1%	23.6%
Cultivation countryside	59.1%	6.8%	0	6.8%	27.3%
Sparsely populated countryside	70.8%	0	4.2%	4.2%	20.8%

Table 23. New construction on the plots of demolished blocks of flats.

Since tenure and the building type affect the range of measures owners can conduct, Figure 15 shows the building and tenure types of all homes demolished between 2000–12. A comparison to tenure types of vacancies reveals that rental homes are overrepresented amongst demolished homes in comparison to vacant homes. Alas, the data does not allow distinguishing between professional and non-professional private owners. However, a significant share of demolition in the private rented stock took place in multi-family buildings, which implies to professional ownership. As could be expected, almost all demolished owner-occupied homes are detached houses. They are also more prevalent in the whole of the demolished stock than in the problematically vacant part of the stock, let alone the normally vacant part.

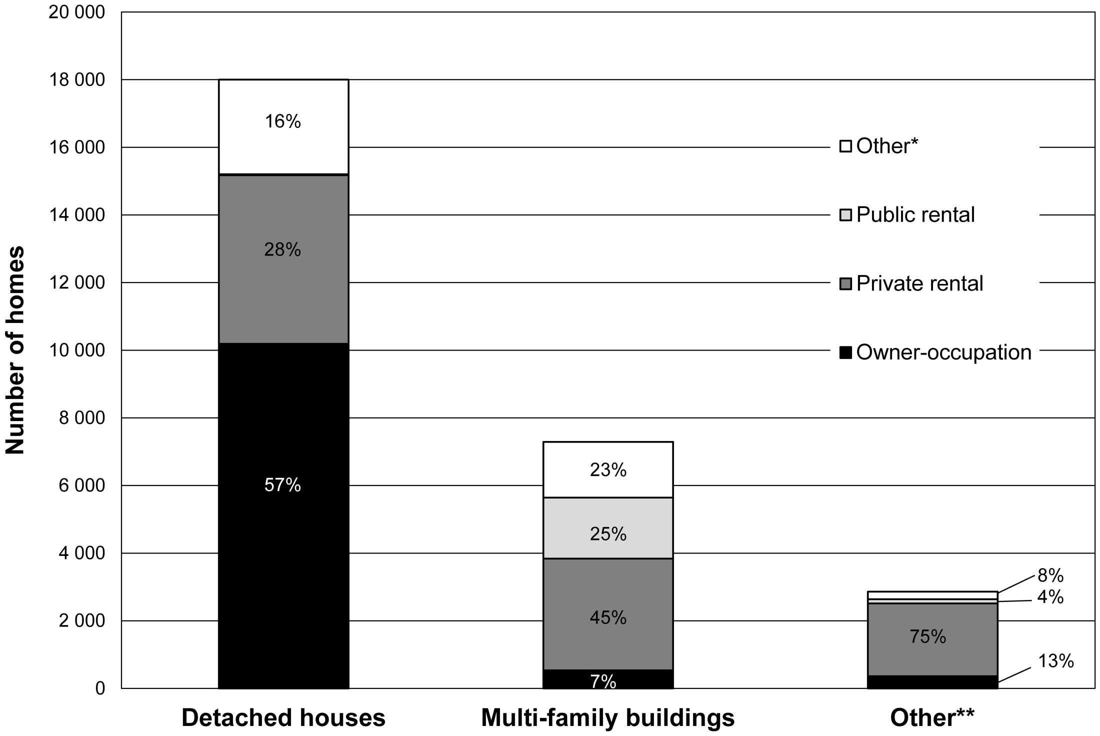

Figure 15. Numbers of demolished homes with different building and tenure types. * Other tenure types include right of occupancy and unknown tenure. ** Other buildings include NRB and unknown building types.

5 Discussion

5.1 On vacancy in Finland

Finnish vacancy rates are remarkably high compared to many other countries (see Table 2). The national average is 12.7% and there is no single municipality where the overall vacancy rate would be less than 5%, the proportion considered as the upper limit for normal transaction vacancy. Instead, half of Finnish municipalities have a vacancy rate between 20% and 46%. The average of municipalities, 19.8%, is perhaps the best indicator for the big picture because the largest cities skew the national average downwards.

However, the Finnish vacancy rate is not unprecedented in the European context, where it seems to couple with those of East and South European countries as declared by Norris and Shiels (2004). The magnitudes of the European vacancy rates seem to challenge the estimates for normal transaction vacancy. Hoekstra and Vakili-Zad (2011) and Vakili-Zad and Hoekstra (2011) have sought for explanations for the Spanish and Maltese vacancy rates from welfare state ideology and strong homeownership culture. Both these remarks apply to Finland as well (Tanninen, 2004), so they might offer a partial explanation. In addition, holiday residence has been though to explain the high vacancy rates around the Mediterranean (Norris & Shiels, 2004). Although its nature is fundamentally different from the Southern tourism industry, the phenomenon of holiday residence is also rooted in Finland. Yet, the operational expenses and environmental stresses of empty homes are significantly higher in the North than in the South as the buildings consume heating energy during the winters. Although these expenses seemingly fall on the private sector, vacancy has implications for the society as well, for instance, in the form of energy consumption, emissions, infrastructure underutilization and shrinkage sprawl.

Although vacancy rates are higher in shrinking settlements, the population decline alone cannot explain the magnitude of the Finnish vacancy rate as Norris and Shiels (2004) have suggested. Due to the sheer size of the housing stock in cities, there are much more vacant homes in the urban than in the rural, and this applies to long-term vacant homes as well.

5.2 On problematic vacancies

This paper considers buildings with high rates of long-term vacancies as 'problematic', *i.e.* as being at risk of becoming demolished. Demolition policies are quite common in other countries (Kruythoff, 2003; Power, 2008; Gilbert, 2009; Mallach, 2011), and Thomsen and van der Flier (2011) have pointed out that policies have a tendency to favour demolition over reconstitution. Despite of no such policies existing in Finland for the time being, the Finnish demolition rate is already one of the highest in Europe (Huuhka & Lahdensivu, 2014). Although the share of problematic vacancies is higher in the older cohorts, the total number of homes in them is small. The largest numbers of vacancies occur in the largest cohorts, even though the relationship with the size of the stock is otherwise not linear. The vast majority of problematically vacant homes are in private ownership. In the buildings with problematic vacancies, there is nearly equally as much floor space in blocks of flats and detached houses. Timber embedded in detached houses is the most significant building material that could originate from this stock. *In situ* cast concrete is another significant material, and this group can be expected to withhold partially prefabricated buildings with panel facades as well. Only little under 15% of the floor area is completely prefabricated, most often from concrete, possibly enabling component extraction.

The proportion of problematic vacancy is the higher the more rural the geographical area is. The proportion of vacant homes is also the higher the more there are over 65-year-olds in the municipality. These observations coincide with Nordvik and Gulbrandsen's (2009) findings about Norway. The demographic development in Finland has been very similar to Norway: Aro (2007) has labelled the period 1945–75 as 'an era of concentration'. He concludes that the development has been inevitable and irreversible: 'Over a period of over 100 years, no single administrative procedure has been able to reverse the direction of migration or its target areas but temporarily and locally at most' (Aro, 2007, p.302). Mukkala (2002) has also concluded that the problem concentrates on peripheral Finland. However, the share of problematic vacancy is greater than the share of normal transaction vacancy in most cases regardless of the location. This is in line with Couch and Cocks' (2013) findings on

England, where even in the strong market of London the share of structural vacancy was as high as 45%. A major difference is that while the overall vacancy rate of London is 2.5%, the vacancy rates of Finnish cities exceed 5%. In the latter, problematic vacancies touch every second row house and over 40% of blocks of flats that have empty homes. What is more, problematically vacant detached houses and row houses are spread on a very vast geographical area. Problematically vacant blocks of flats, instead, concentrate on cities; and they contain the highest share of floor area of all buildings at risk. Despite the extent of the phenomenon, Finland currently has no policies for reducing vacancies.

5.3 On the development of communities

The building stocks and the geographical areas of settlements have been found to keep growing in all Finnish municipalities despite the fact that two-thirds of them have shrinking populations (Huuhka, 2014). The current study points out that at the same time, tens of percent of the existing housing stock is vacant in many municipalities. Thomsen and van der Flier (2011) have aptly pointed out that obsolete buildings on valueless land will not be demolished. Even though the literature on shrinkage sprawl underlines its many disadvantages to the community (*e.g.* Siedentop & Fina, 2010; Reckien & Martinez-Fernandez, 2011), municipalities keep granting building permissions for new construction on virgin land and the current Centre party-led Finnish government is set to ease turning the scattered holiday housing into permanent homes (Valtioneuvoston kanslia, 2015, p.12). On the other hand, growth centres suffering from housing shortages and high housing prices demolish the largest numbers of housing and, yet, have larger reserves of vacant housing than what is considered as normal for a functional housing market.

Studying past replacement of residential buildings by building type was intended to shed more light on the current, lightly-regulated replacement behaviour. As changing the intended use of a plot requires re-zoning in urban areas, it could be expected that buildings would be most often replaced by the same type of buildings. On the other hand, it could also be anticipated that small buildings would be replaced with larger ones. The former assumption proved to apply to detached houses and blocks of flats, and the latter to row houses. Exchange into non-residential buildings was remarkable, especially with row houses but also blocks of flats. However, it should be noted that there were significant differences in the replacement behaviour between urban and rural areas. The findings on tenure types suggest that the limitations posed by shared ownership as described in Thomsen and van der Flier (2009) would, indeed, have an effect on the demolition of buildings.

5.4 Does housing vacancy reflect non-residential vacancy?

Although the study is based on examining residential buildings, there is an underlying assumption that the amount of vacancies in residential buildings (RB) would also reflect that in non-residential buildings (NRB). Because data on non-residential vacancy is not available, this could not be verified. However, the assumption is based on two other observations. Firstly, the number of RB and NRB in Finnish municipalities correlate linearly (r=0.94), and so do their floor areas (r=0.99). Secondly, the number of demolished RB and NRB (r=0.91) and their floor areas (r=0.84) correlate linearly, although the coefficients are slightly smaller. In addition, it has been generally accepted that population decline is connected to structural changes in industrial and agricultural production, which suggest that the decline would have an effect on the non-residential building stock.

Conclusions

This study offers new evidence-based insight into vacancy in Finland and the relations between the housing stock, vacancy and demolition. On top of half a million holiday homes, there were 382 802 Finnish homes (12.7%) that were not permanently inhabited. The average municipal gross vacancy rate was 19.8%. The tenure-type-related average municipal vacancy rate was lowest for owner-occupied housing (16.0%) and highest for private rental housing (29.0%), with social housing (25.0%) in-between the two.

The six hypotheses set were found to stand. Firstly, vacancy rates were related to demographics: they showed negative correlation with population and population change, and positive correlation with the share of the elderly. Secondly, the extent of vacancy depended on the location: vacancy was more severe in rural areas. Thirdly, the size of housing stock correlated negatively with the vacancy rate but positively with the number of vacant homes. Fourthly, building type also had an effect: vacancy was more severe in detached houses than in multi-family buildings, although a larger share the latter was touched by (normal) vacancies. Fifthly and sixthly, vacancy was not straightforwardly related to building age or demolition: problematic vacancies prevailed in older cohorts, but the vacancy rates of cohorts differed between building types; and demolition rates showed no correlation whatsoever with vacancy rates.

A comparison with past new construction and demolition was carried out to assess the magnitude of the reserves in the underutilized housing stock. Depending on the building type, the size of the reserve is 4–17 times the annual new construction. Although cities have the lowest vacancy rates, quantitatively largest and geographically most concentrated reserves are found in cities, where the housing needs are also the most apparent. The challenge is whether the need and demand meet in the same submarkets. On the other hand, if the underutilized housing stock was to be demolished, it could be considered as a possible reserve for building components or, at worst, a source of demolition waste. The floor area in the stock is significant in magnitude: depending on the building type, 10–58 times as much as demolished in 2000–12. Removing it would denote a significant increase in waste production, or a notable reserve for building parts and materials, depending on whether demolition or deconstruction was employed. Although this study suggests that a lot of this removal should take place in the countryside, previous research (Huuhka & Lahdensivu, 2014) has shown that in practice, most of demolition occurs in cities.

Policy implications

Understanding the true magnitude of empty homes should have implications for policies regarding housing and sustainable urban development as well as energy and resource conservation. It should affect the deliberation regarding zoning of virgin land, granting of building and demolition permits and allowing holiday homes to be turned into permanent residences, as well as energy use allowances for irregularly used buildings. To address the empty homes themselves, policies could include increasing demolition (and, in parallel, recycling) and encouraging reconstitution and more permanent usage. The decision-making should be backed up by similar but more local investigations into the building stock as the approach presented in this paper.

The Finnish legislation does already encompass tools, similar to those in the US (Hackworth, 2014), that authorities could employ, especially in the context of shrinking communities. First of all, allowing buildings to blight is forbidden, and building authorities have the right to order a blighted building to be repaired or demolished (Maankäyttö- ja rakennuslaki [MRL], 1999, §§ 166, 170). If the owner refuses, authorities can impose conditional fines or have the measures done at the owner's expense (MRL, 1999, § 182). Authorities also have the right to use eminent domain (expropriation) and pre-emption (MRL, 1999, § 99; Etuostolaki, 1977, § 5). However, Finnish planning has been argued to be fundamentally entangled with landowners' interests (Mäntysalo & Nyman, 2001), of which it is symptomatic that authorities prefer not use these tools. This applies especially to eminent domain, which also requires permission from the ministry, possibly discouraging authorities further. As for pre-emption, the conditions set for it in the law prevent the purchase of normal-sized urban plots, since only plots larger than 5000m^2 may be acquired this way. This limitation makes pre-emption less usable within the existing fabric, unless the municipality declares the area a 'development zone' (MRL, 1999, § 112).

It should be discussed if the provisions on eminent domain and pre-emption could be reformed to allow an easier usage against property abandonment. However, these tools consider only pieces of real estate, leaving housing companies (row houses and blocks of flats) out of their scope. Moreover, an equally important question is how to address simultaneous vacancy and housing shortage in growth centres, where most homes are located in multi-family buildings. The current mechanisms require that the owner has fallen into financial difficulties. For instance, the law on housing companies provides the company a way to take over a home for a term if a shareholder is neglecting the maintenance charges (Asunto-osakeyhtiölaki, 2009, 8:2,6). This enables the company to rent the home in order to cover the debts. In shrinking communities, the opportunity to find tenants may be weak (Vaara, 2014). Authorities can also hold compulsory auctions as a form of debt recovery proceedings. Although the number of forced sales have increased in the last years, the volumes are negligible compared to the size of the housing stock: in 2014, 561 homes in housing companies and 1264 pieces of real estate were auctioned (Valtakunnanvoudinvirasto, 2015, pp.22–23). This implies that property abandonment in Finland is, in Hackworth's (2014) terms, rather 'functional' than 'literal', meaning that proprietors prefer not to relinquish ownership formally.

Furthermore, it can be speculated that many vacant homes are used irregularly and their owners have no problem with affording it. In Helsinki, most areas with high vacancy rates are high society neighbourhoods, whereas the lowest rates occur in areas characterized by social housing (Taipale, 2015). With this regard, the UK Housing Act that enables authorities to force unused dwellings into use is interesting (although second homes have factually been limited outside its scope), but such ideas would hardly comply with the Finnish mentality. In future, however, the issue should be addressed in the name of energy and resource use. Personal carbon or energy allowances (see *e.g.* Fawcett, 2010) could be one opportunity for achieving results.

Future research opportunities

Since the implications of vacancy are not only financial but also social and environmental, further multidisciplinary research is still needed to create a holistic understanding of its different aspects. Especially the knowledge on context-related drivers should be deepened further. A first step in this work should be a review paper that would gather the knowledge from existing studies, followed by a meta-analysis if possible. Future research opportunities include collecting data from other countries, on the non-residential part of the building stock and longitudinal data as well as taking advantage of multivariate regression modelling and other refined statistical methods. In future, dynamic building stock models could perhaps be developed to include vacancies as one variable. Possible policy responses to vacancy in growth contexts would also deserve more academic attention.

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ORIGINAL PAPERS

III

REUSING CONCRETE PANELS FROM BUILDINGS FOR BUILDING: POTENTIAL IN FINNISH 1970S MASS HOUSING

by

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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.

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).

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

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

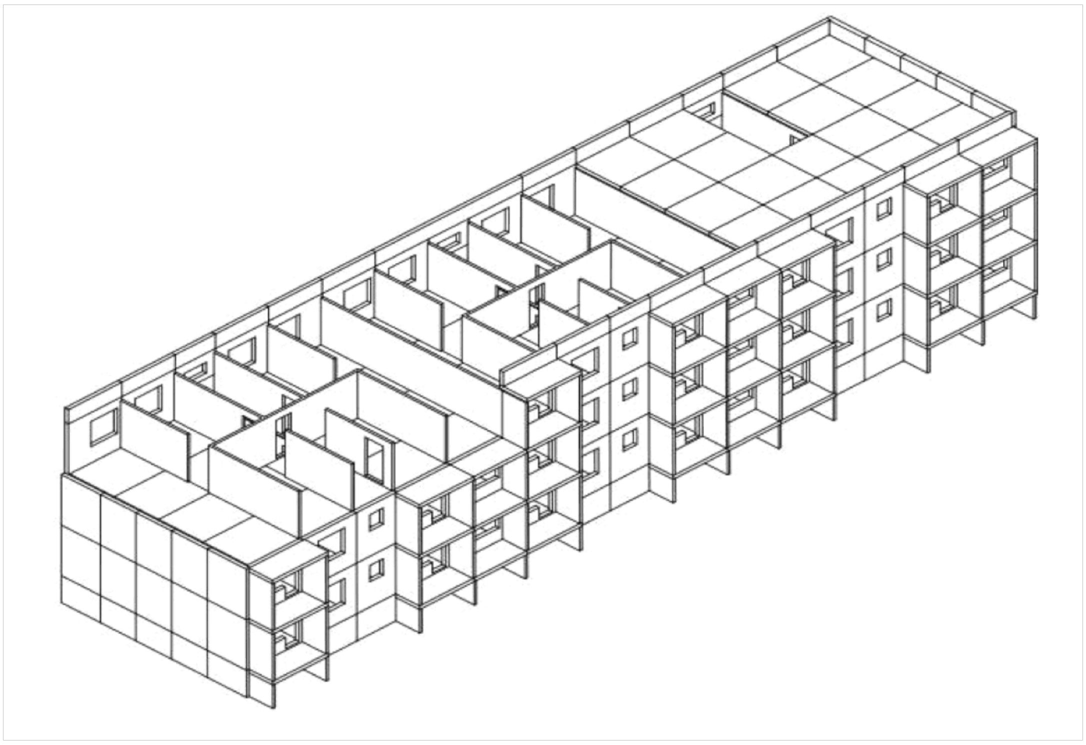

Figure 1. Finnish large-panel system used from 1960s to 1975. Both panels and slabs were room-size. Interior walls between rooms are load-bearing. (Remodeled from Mäkiö et al., 1994, p. 67).

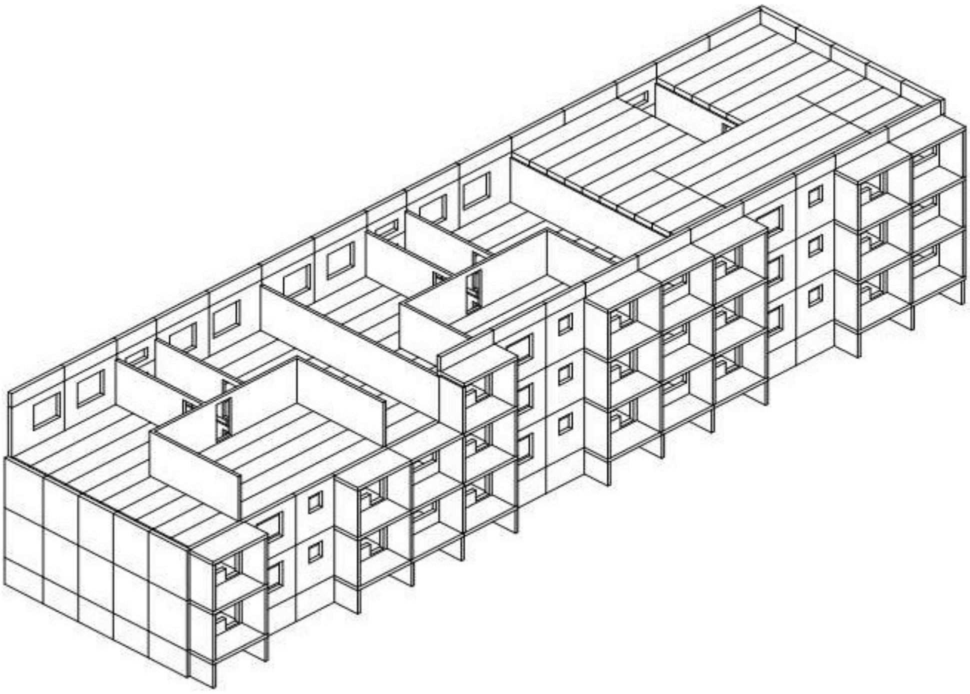

Figure 2. BES system. Main differences to the large-panel system (Figure 2) are the long-spanning hollow-core slabs and the subsequently smaller number of load-bearing interior walls. Only interior walls between apartments are load-bearing. (Remodeled from Mäkiö et al., 1994, p. 68).

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.

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

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

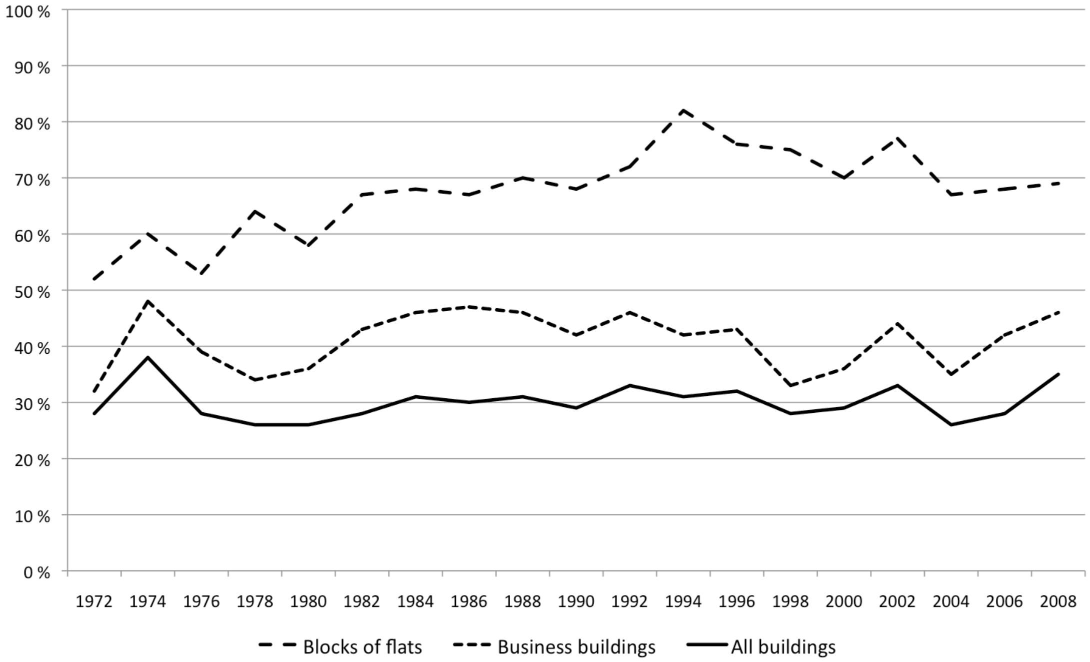

Figure 3. Share of prefabricated concrete in Finnish building production. (Remodeled from Hytönen & Seppänen, 2009, p. 325).

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).

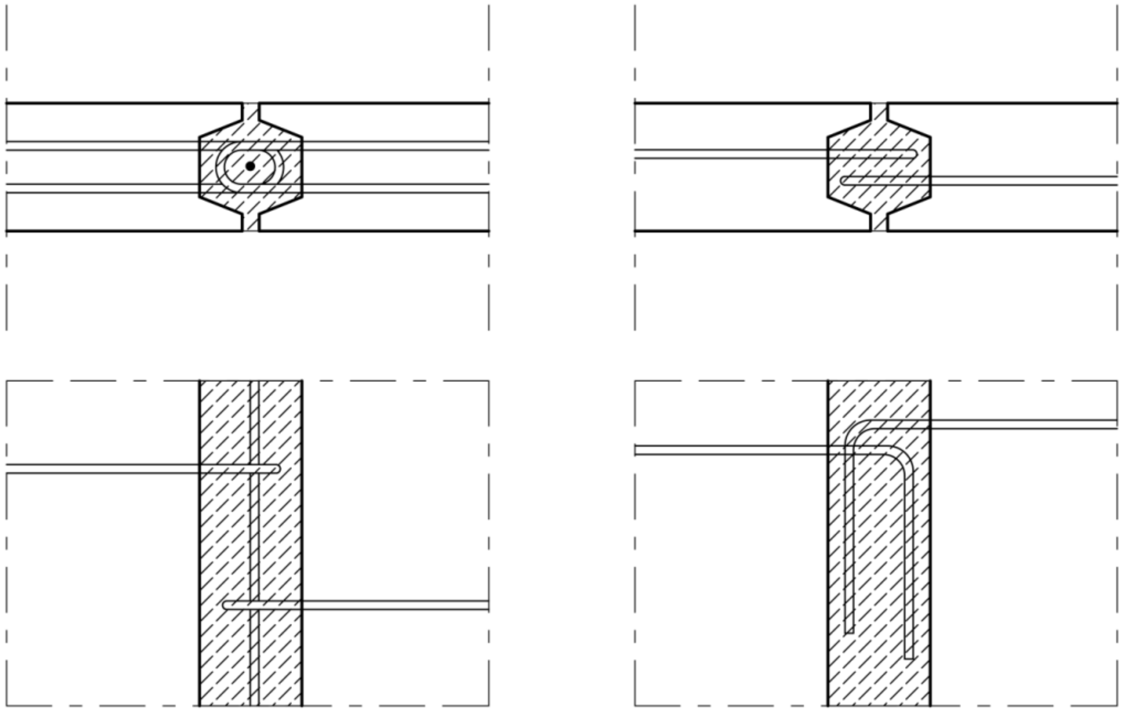

Figure 4. A steel loop connection (left) and a steel hook connection (right). (Redrawn from BES-suositus, 1972).

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.

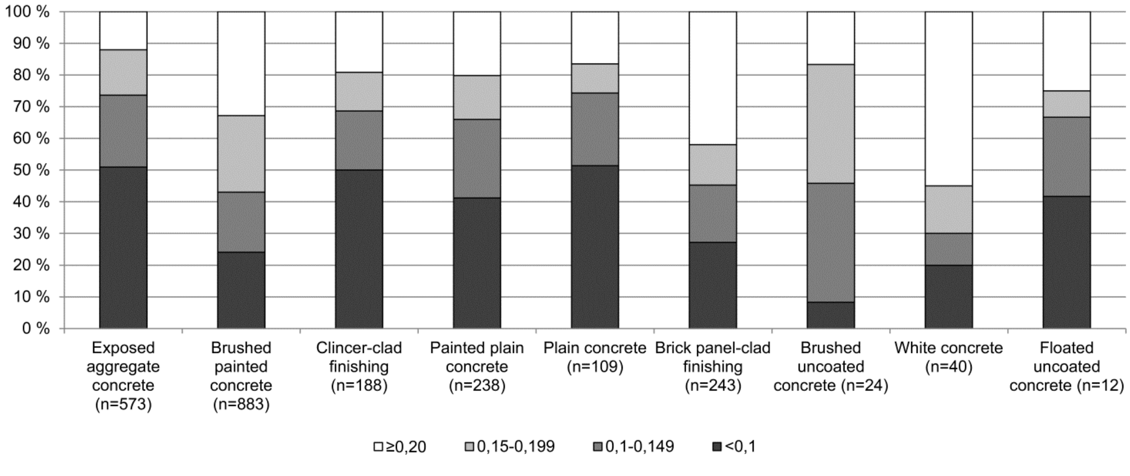

Figure 6. The distribution of protective pore ratio in different surface finishings of concrete facades (Lahdensivu, 2012).

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.

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

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

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

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.

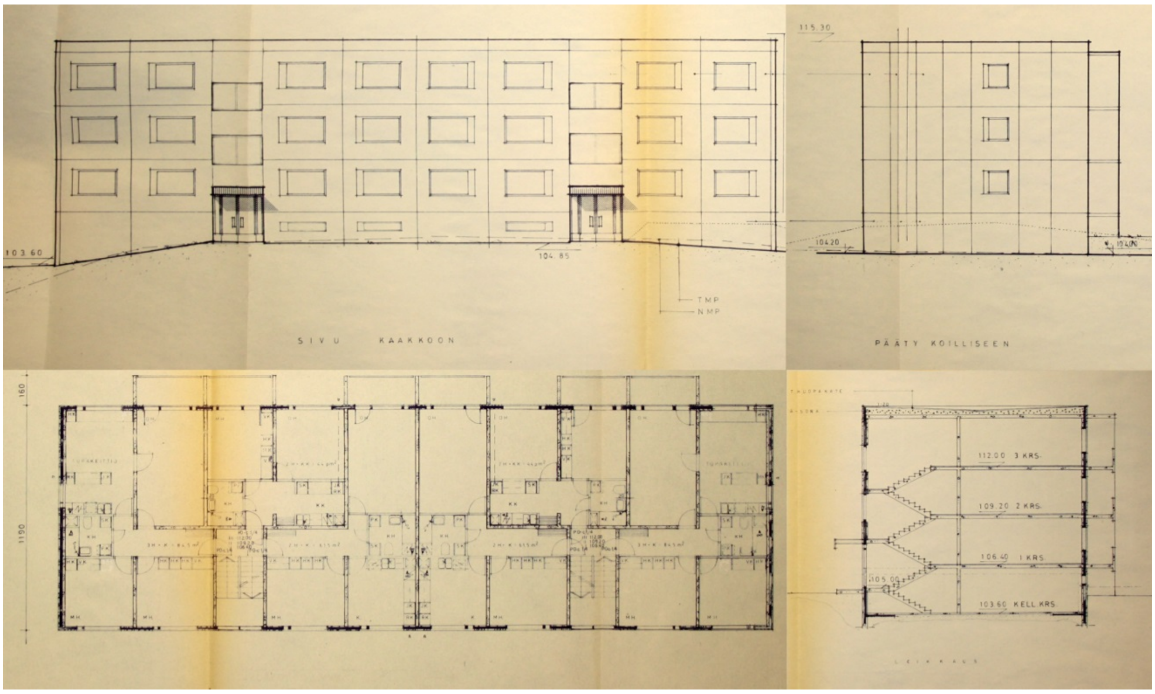

Figure 8. An example of original facade, plan and section drawings of a building.

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.

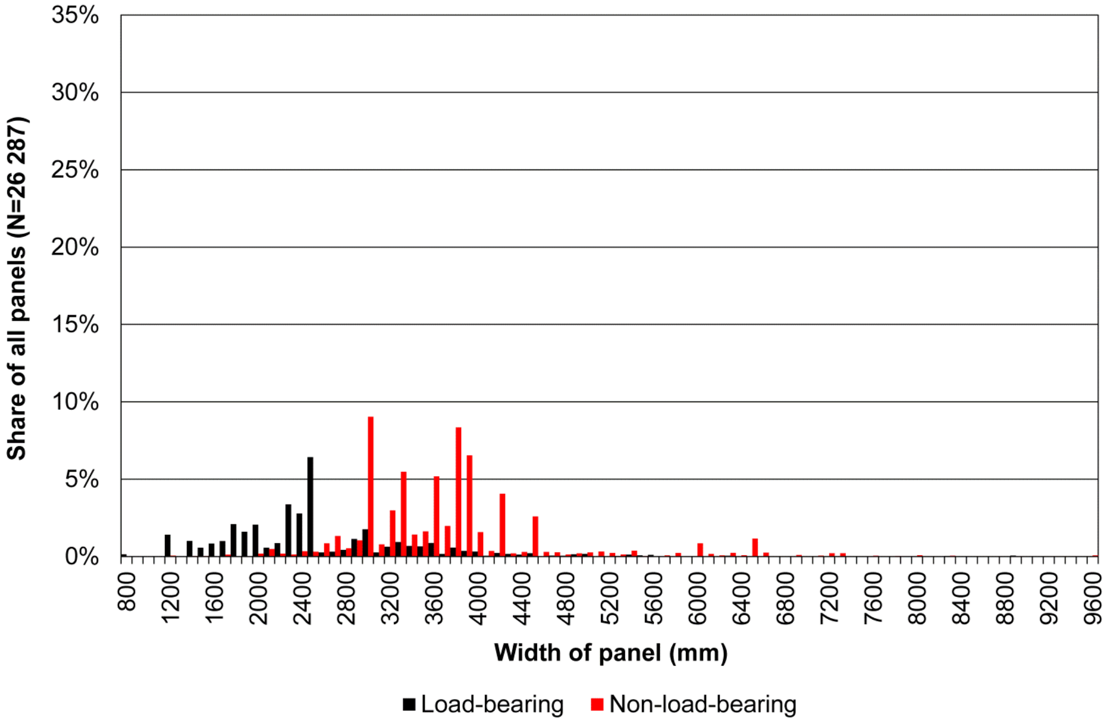

Figure 9. Width distribution of panels (N=26 287 panels).

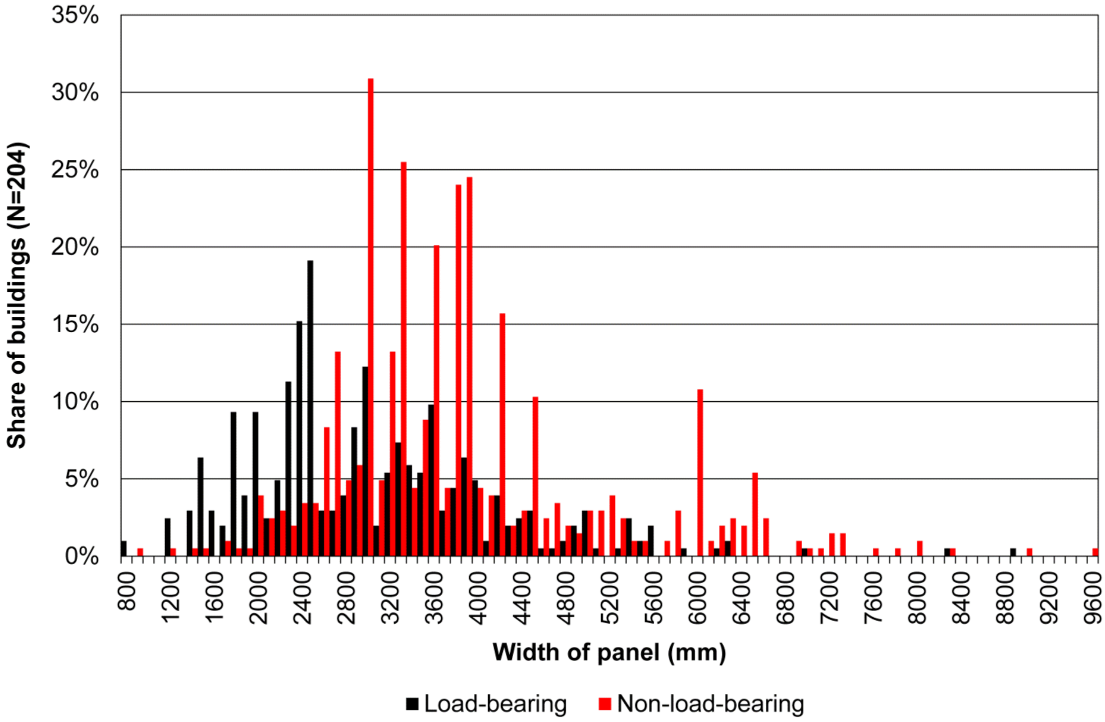

Figure 10. Occurrence of the widths in the in buildings (N=204 buildings).

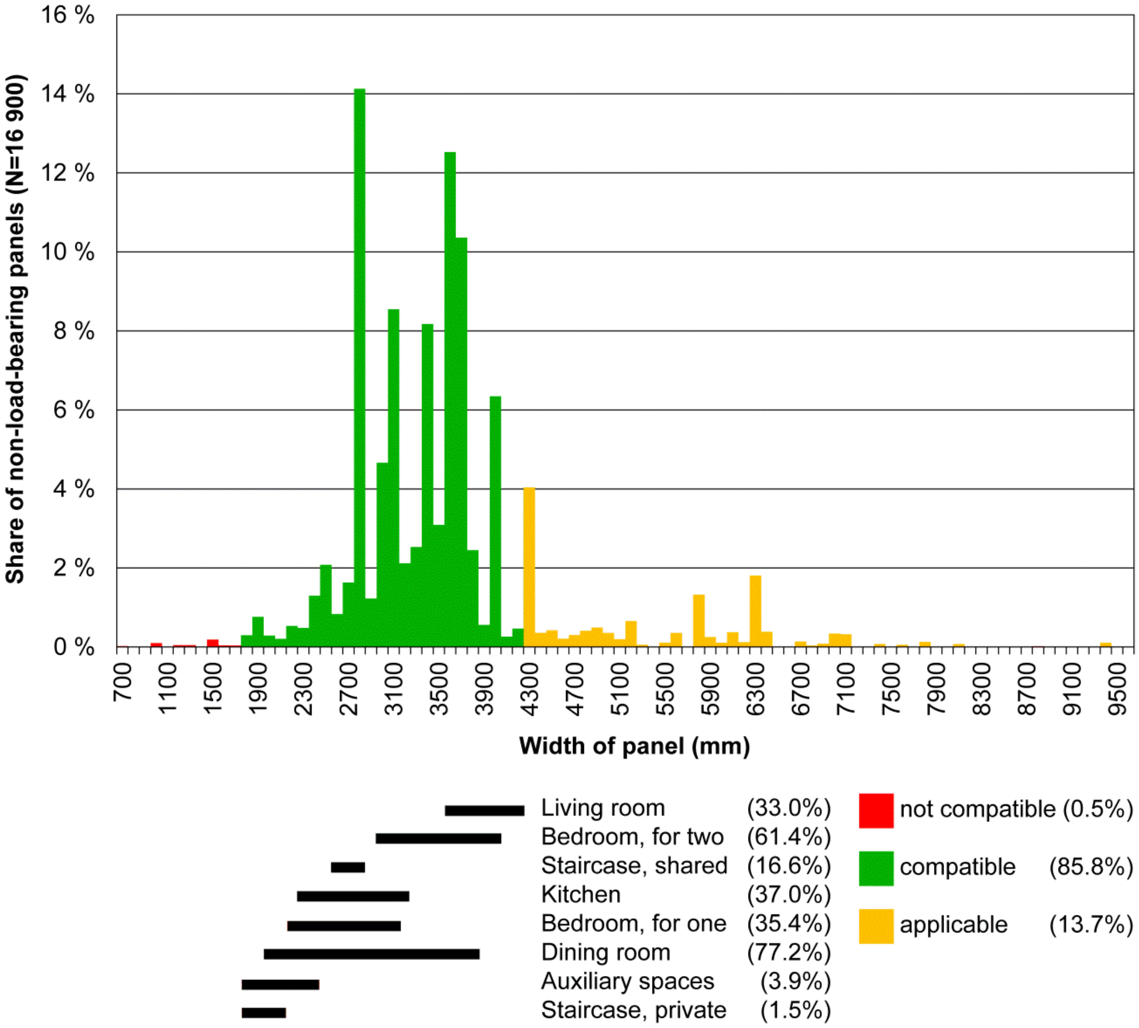

Figure 11. Compatibility of non-load-bearing panels to currently recommended dimensions for different rooms (N=16 900 panels).

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

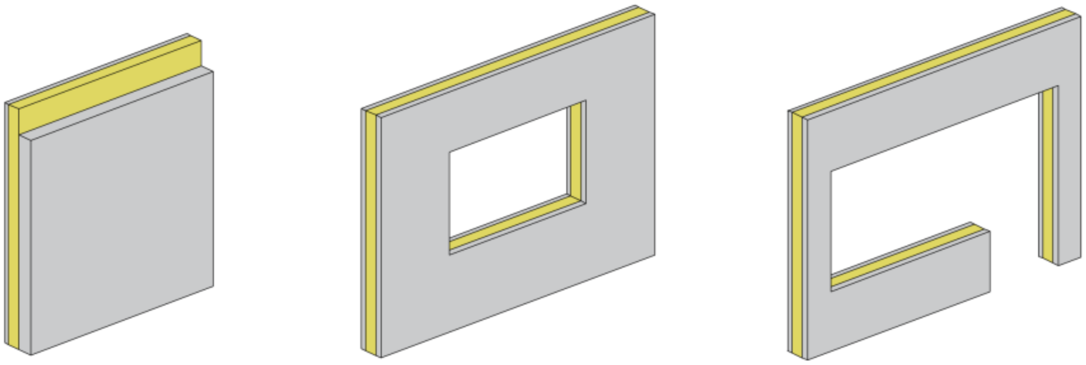

Figure 12. Main panel types from left to right: blind load-bearing panel; typical non-load-bearing panel with a normal window, non-load-bearing balcony back wall panel.

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.

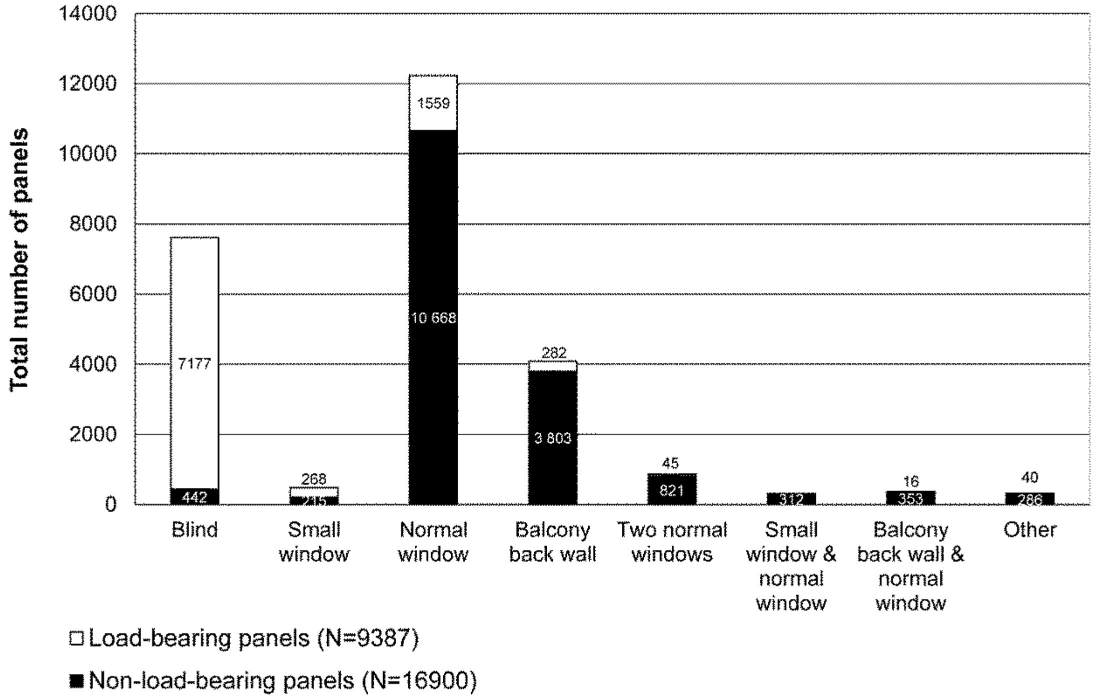

Figure 13. Total numbers of panels for different panel types (N= 26 287 panels). 'Other' includes rare types such as two-room wide panels with three windows, panels with Juliet balconies, etc.

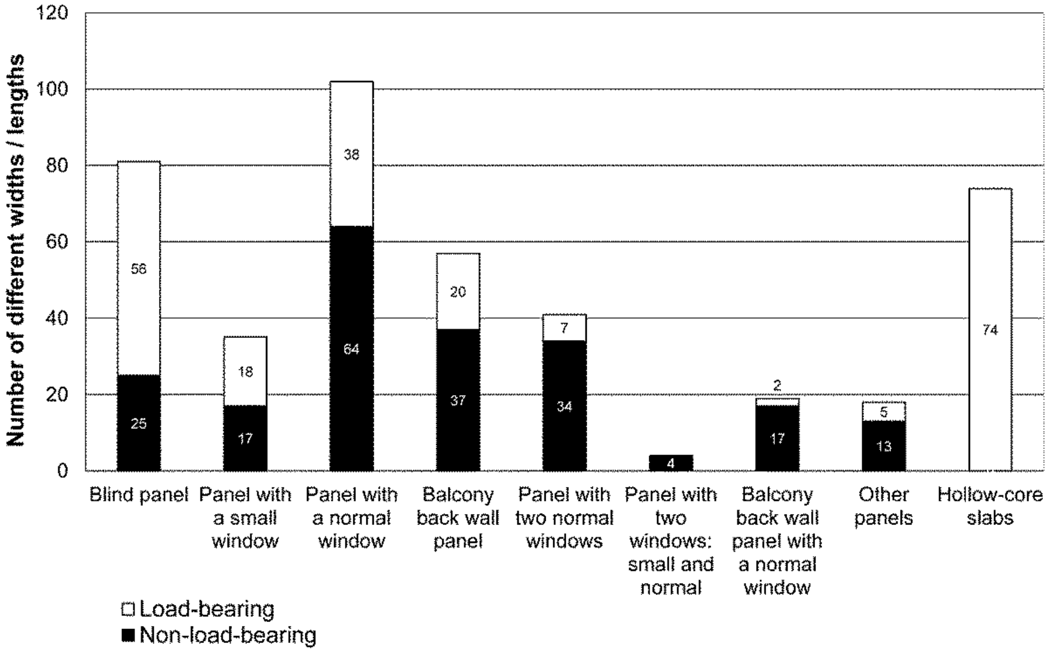

Figure 14. Numbers of individual widths for different panel types (N=431 width-type combinations).

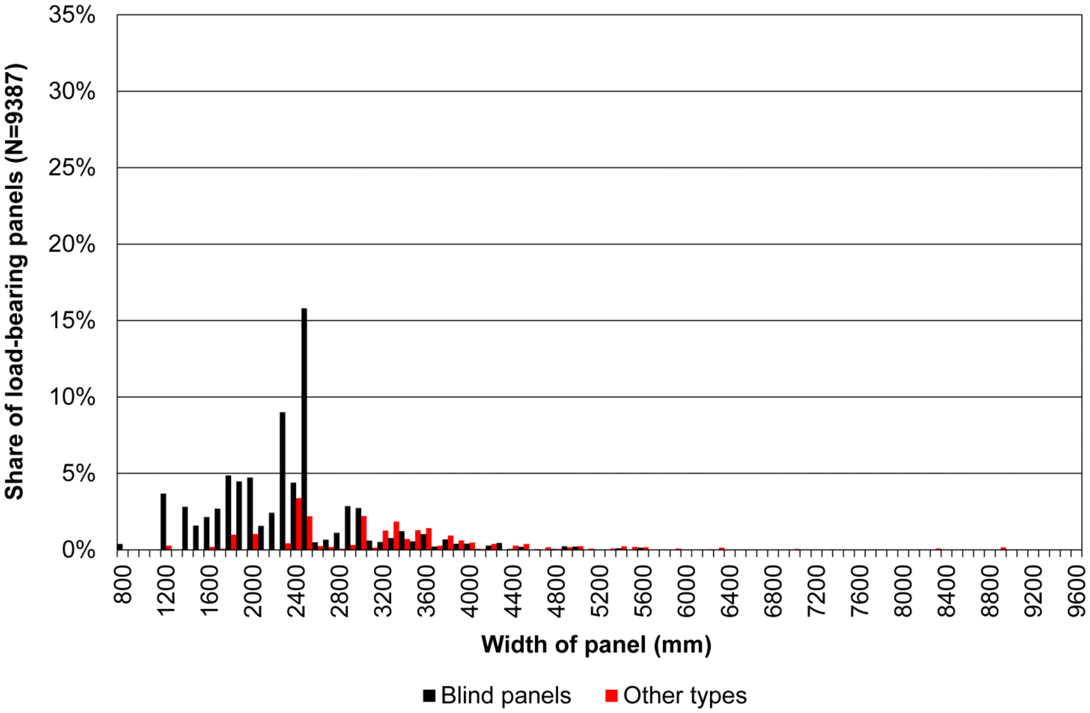

Figure 15. Width distribution of load-bearing panels according to the type (N=9 387 panels).

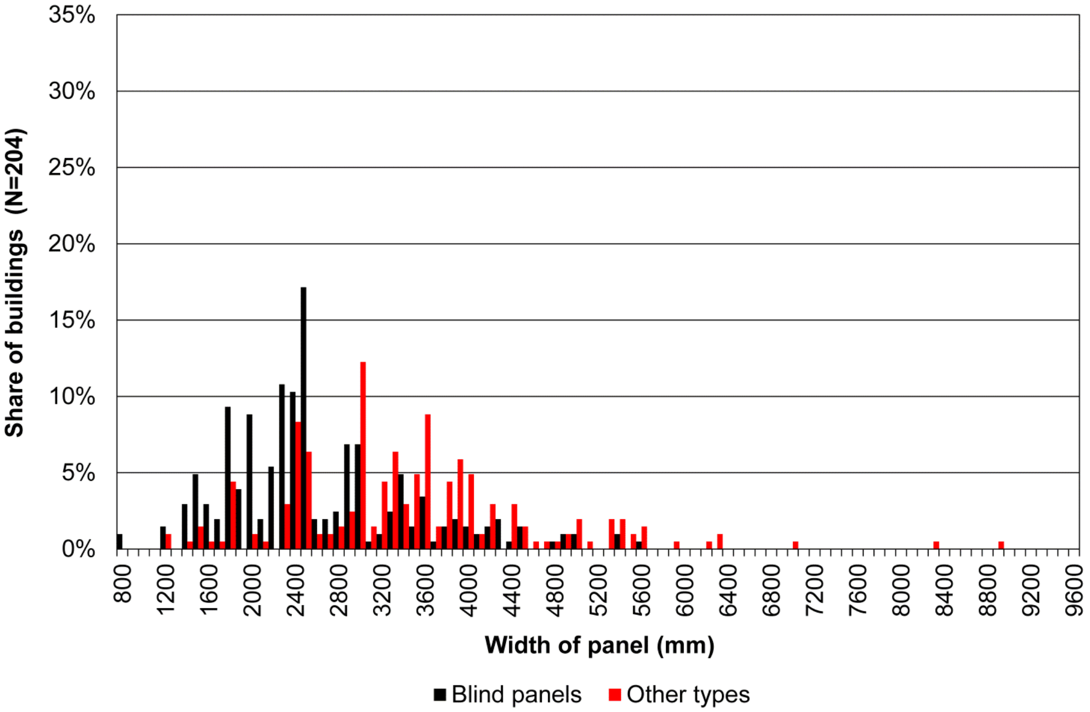

Figure 16. Occurrence of the load-bearing panels in the buildings (N=204 buildings).

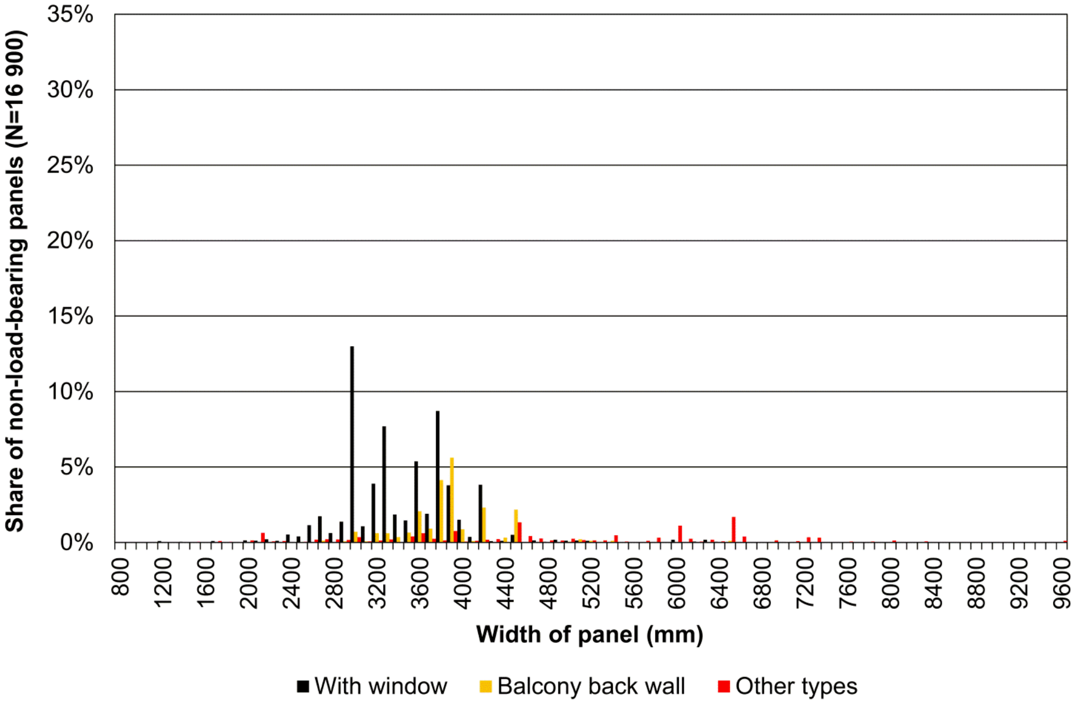

Figure 17. Width distribution of non-load-bearing panels according to the type (N=16 900 panels).

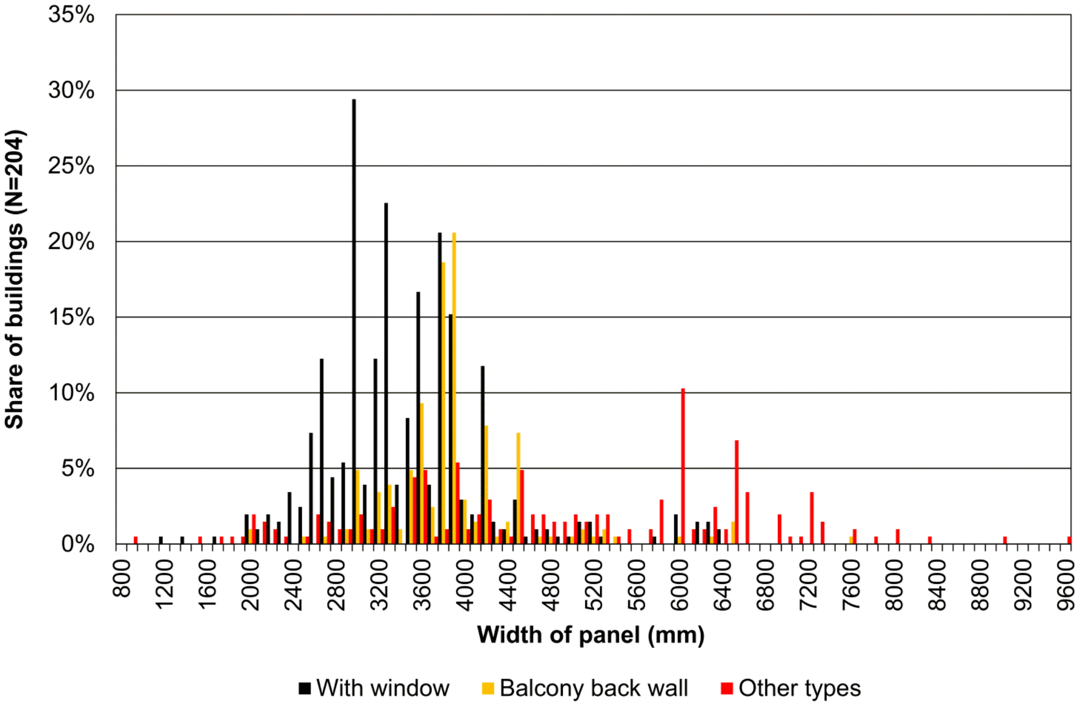

Figure 18. Occurrence of the non-load-bearing panels in the buildings (N=204 buildings).

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.

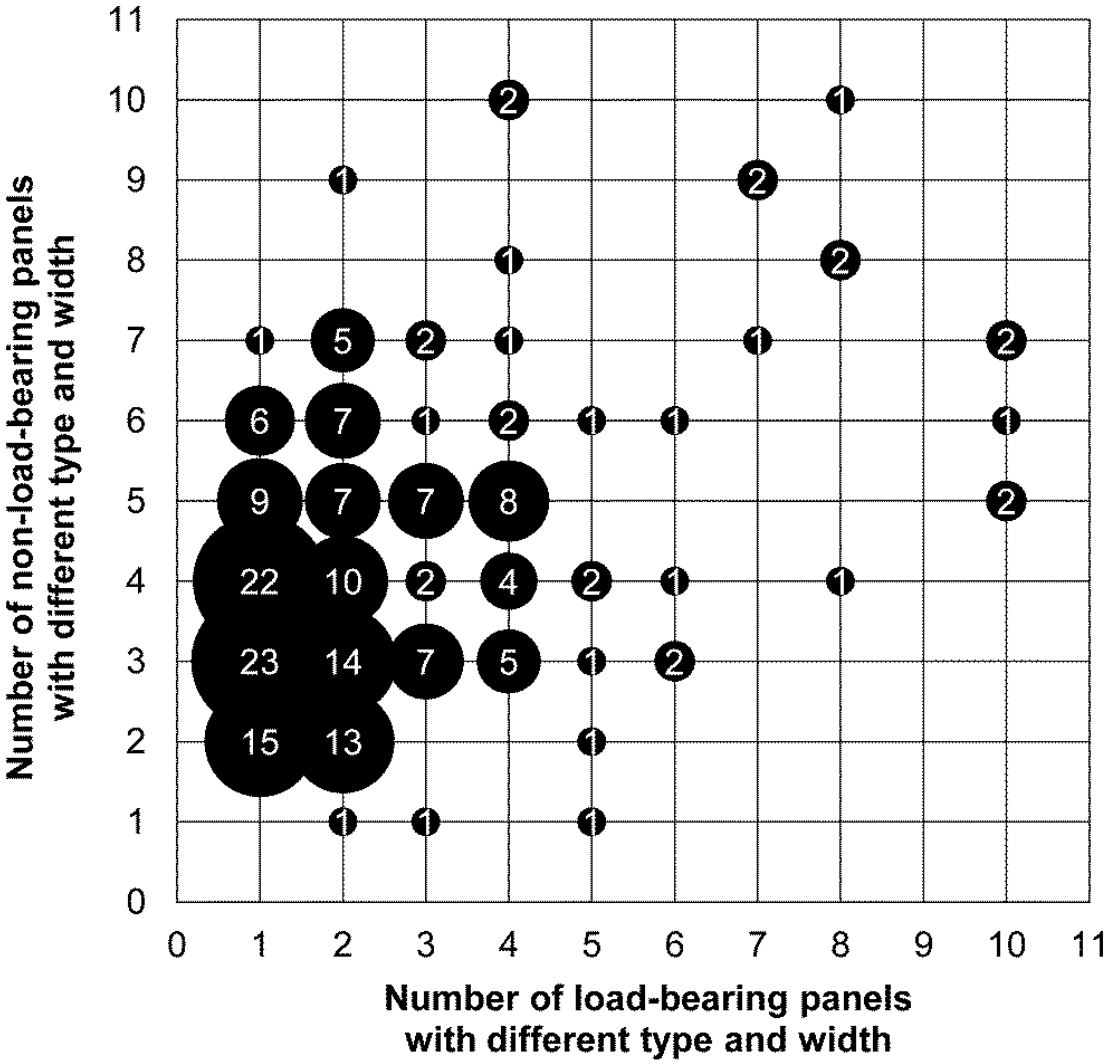

Figure 19. Number of buildings with different number of panels (N=204 buildings).

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.

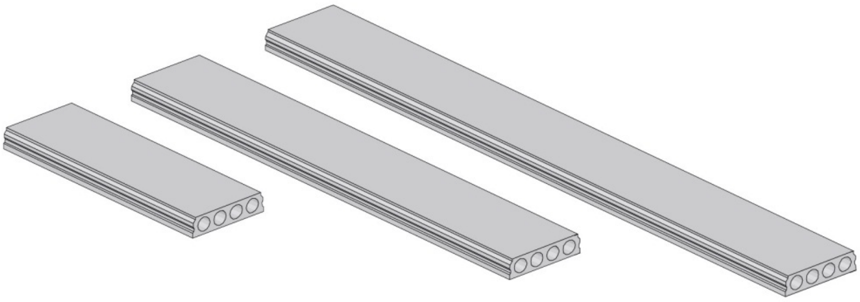

Figure 20. Typical hollow-core slabs: one, two or three rooms long

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.

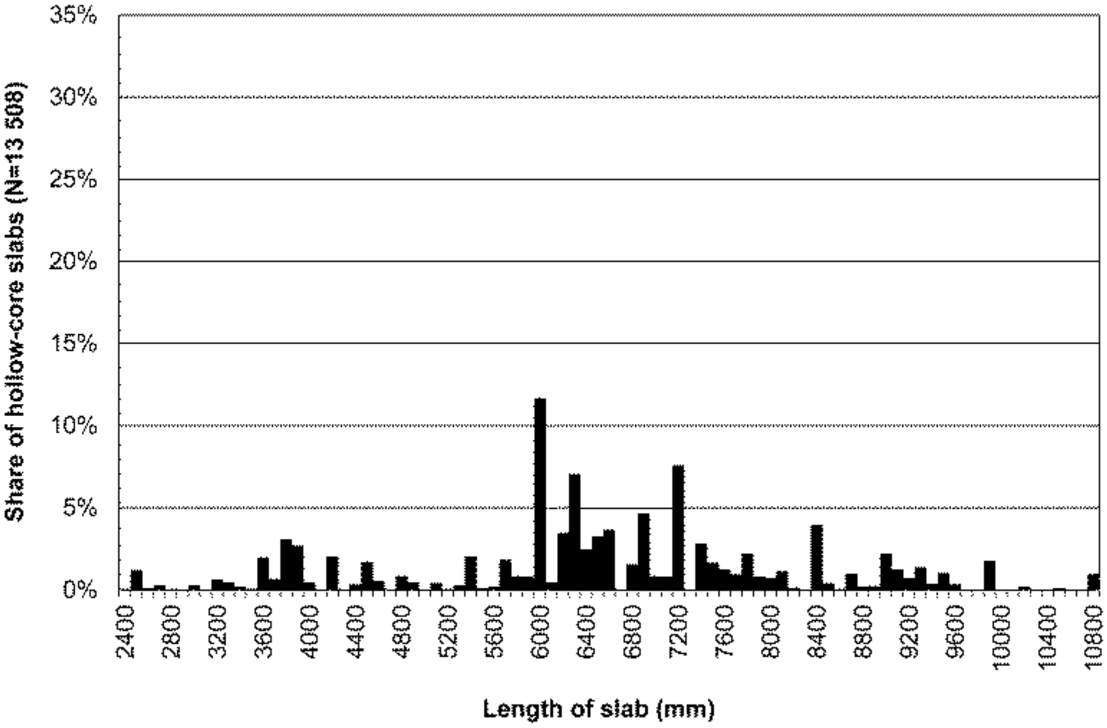

Figure 21. Length distribution of hollow-core slabs (N=13 508 slabs).

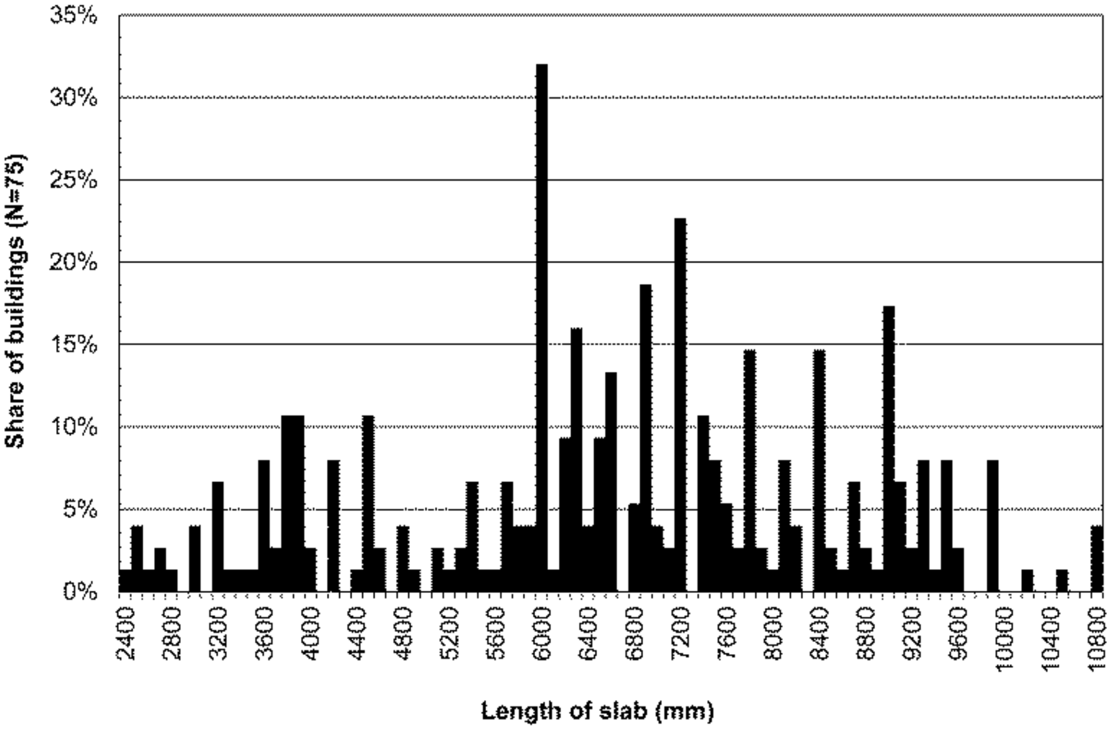

Figure 22. Occurrence of the lengths in the in buildings (N=75 buildings).

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.

	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

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

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.

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 %

*Buildings where the floor structure could be determined

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

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 m2 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 m2 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.

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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ORIGINAL PAPERS

IV

THE HOMOGENOUS HOMES OF FINLAND: 'STANDARD' FLATS IN NON-STANDARDIZED BLOCKS

by

Kaasalainen, T. & Huuhka, S., Feb 2016

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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.

1 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.

2 Background

2.1 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.

2.2 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).

2.2.1 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.

2.2.2 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.

2.3 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 (20m^2), room size (7m^2), 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 120m^2 and the number of small flats (<50m^2) 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 10m^2 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, 1965; RT 930.20, 1974; RT 930.30, 1974; RT 930.40, 1974; RT 930.50, 1974; RT 935.50, 1966; RT 936.50, 1965), but instructional layouts were given only for bedrooms (RT 935.50, 1966; 50 configurations) and bathrooms (RT 936.50, 1965; 26 configurations).

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

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

2.4 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).

3 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 (270 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.

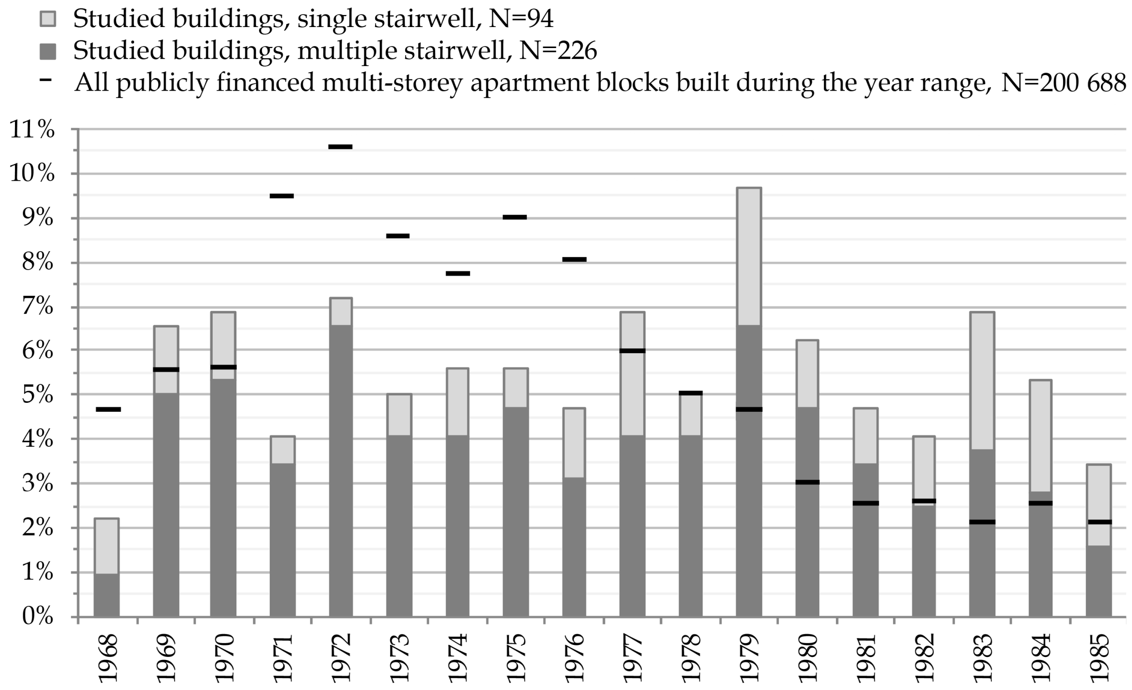


Figure 1. Distribution of studied buildings and all public-funded apartment buildings within the chosen year range. Sources: Authors' research; Kakko, 2011; Laine, 1993.

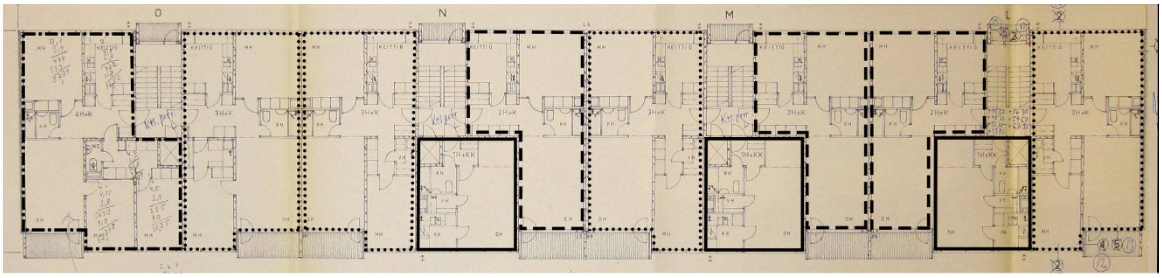
An effort was made to roughly balance the building type distribution to slab blocks and tower blocks by using a ratio of 3:1 (see Figure 1). Based on a comparison sample (N=1125) acquired from ARA's Register of Real Estate (2013), tower blocks were slightly overrepresented among the studied buildings 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.

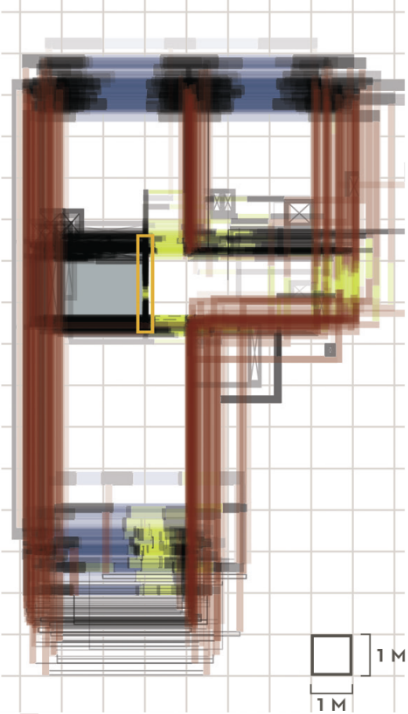
3.1 Defining the flat types

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.



☐ One-room flats ⌜⌟ Two-room flats ⬚ Three-room flats ⌜⌟ Four-room flats

Figure 2. A building plan with flats of different room counts highlighted with simple graphs. Notes: Notes: Kitchens and kitchenettes do not count as rooms. This image is based on a photo of the original document from 1969 provided by the archives of the Housing Finance and Development Centre of Finland (ARA).



■ Wall, load-bearing
■ Wall, non-load-bearing
■ Window
■ Door
■ Bathroom

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 circled bathroom wall. The colour key also applies to Figures 4–8.

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.

4 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.'

4.1 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 between other flats, never in a corner.

	Distribution of recognized flat types within same room count			
Flat type	**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%

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.

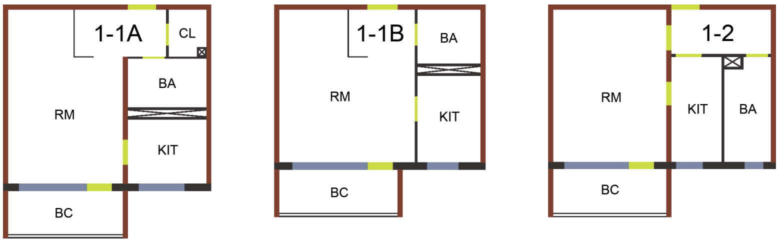


Figure 4. One-room flat types.

4.1.1 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.

4.1.1.1 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.

4.1.1.2 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.

4.1.2 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.

4.2 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.

4.2.1 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.

4.2.1.1 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.

4.2.1.2 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.

4.2.1.3 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.

4.2.2 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.

4.2.3 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.

4.2.3.1 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.

4.2.3.2 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.

4.2.3.3 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.

4.3 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.

4.3.1 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.

Figure 6. Three-room flat types.

4.3.1.1 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.

4.3.1.2 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.

4.3.1.3 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.

4.3.2 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.

4.3.3 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.

4.4 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.

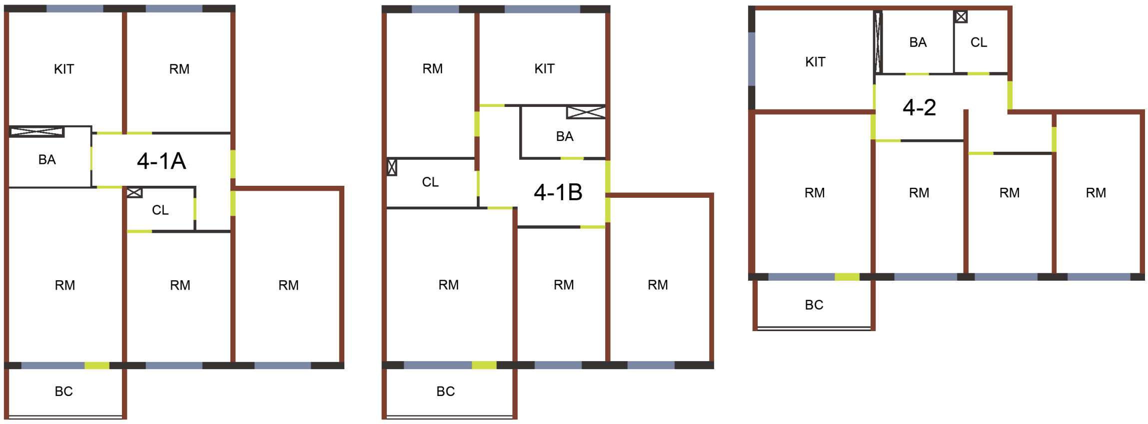


Figure 7. Four-room flat types.

4.4.1 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.

4.4.1.1 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.

4.4.1.2 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.

4.4.2 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).

4.5 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.

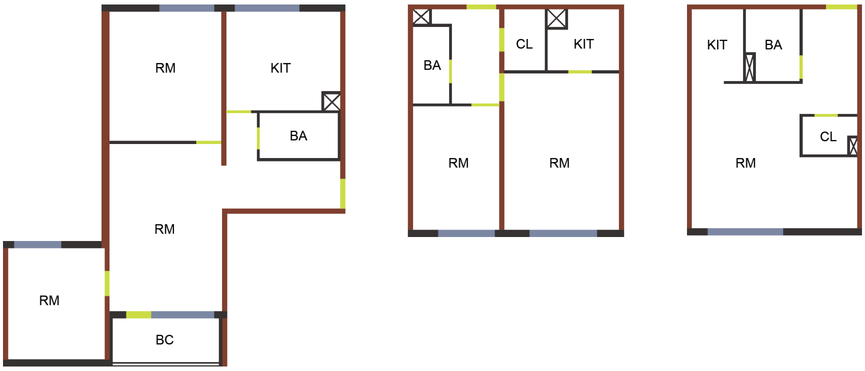


Figure 8. Examples of flats outside the defined types.

5 Discussion

5.1 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.

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

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

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.

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%

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.

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.

5.2 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.

5.3 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.

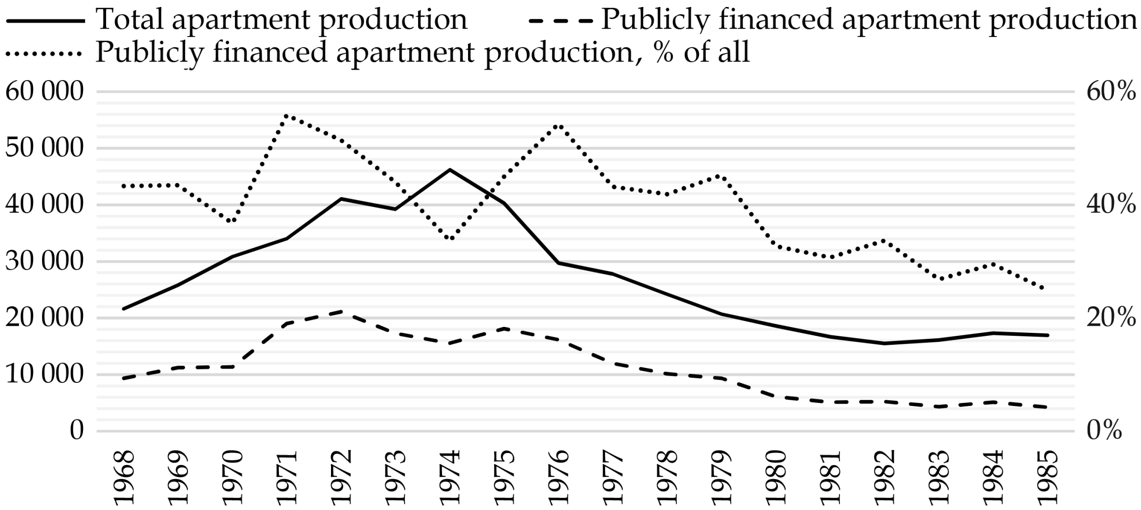


Figure 9. Finnish dwelling production in apartment blocks during the years 1968–1985. Sources: Kakko, 2011; Laine, 1993; Official Statistics of Finland, 2007.

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.

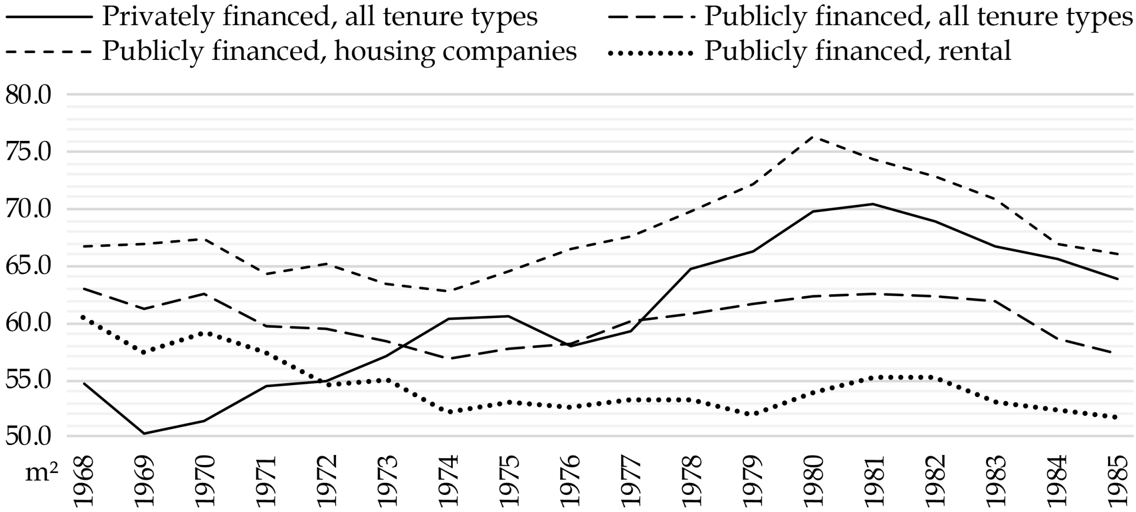


Figure 10. Average dwelling area in apartment blocks and row houses, m². Sources: ARA's Register of Real Estate, 2013; Kakko, 2011; Laine, 1993; Official Statistics of Finland, 2013.

5.4 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.

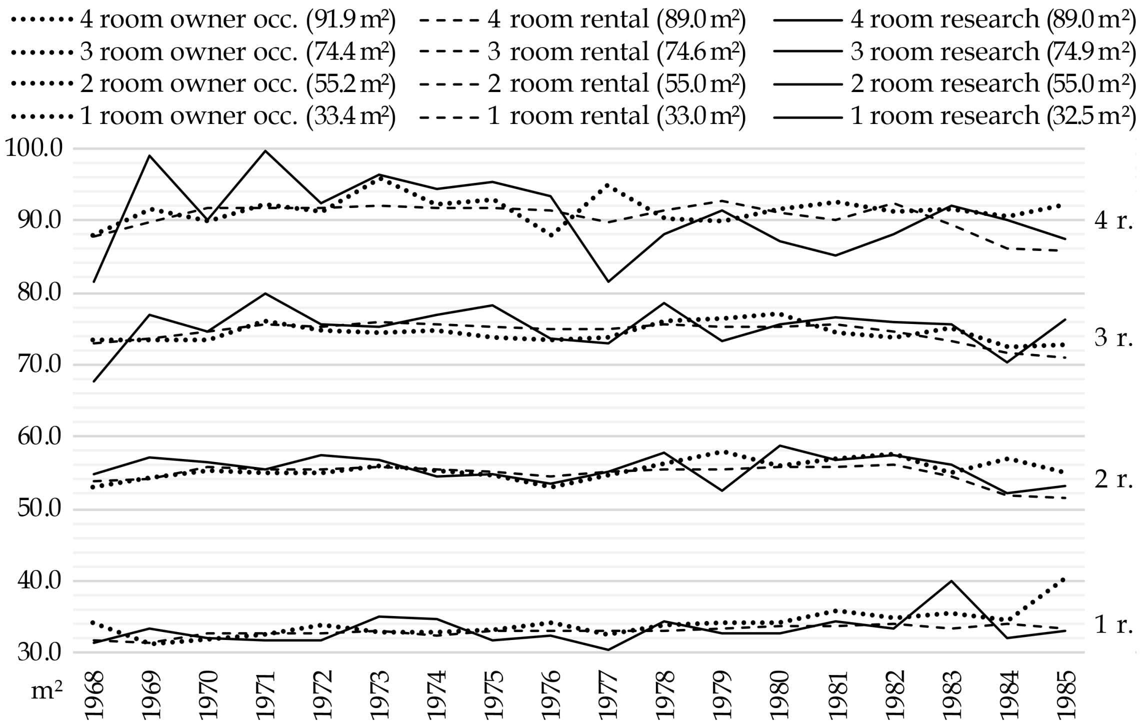


Figure 11. Average dwelling areas in privately and publicly financed owner-occupied flats, publicly financed rental flats and the flats of the research material (both tenure types), m². Sources: ARA's Register of Real Estate, 2013; Authors' Research; Etuovi.com, 2014.

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.

5.5 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.

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 %

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.

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 first 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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