STATISTICAL AND GEOGRAPHICAL STUDY ON DEMOLISHED BUILDINGS

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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 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) 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). Hassler 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. 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, Sereda (1978, as quoted in Holck Sandberg et al., 2014) 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 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 in "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.

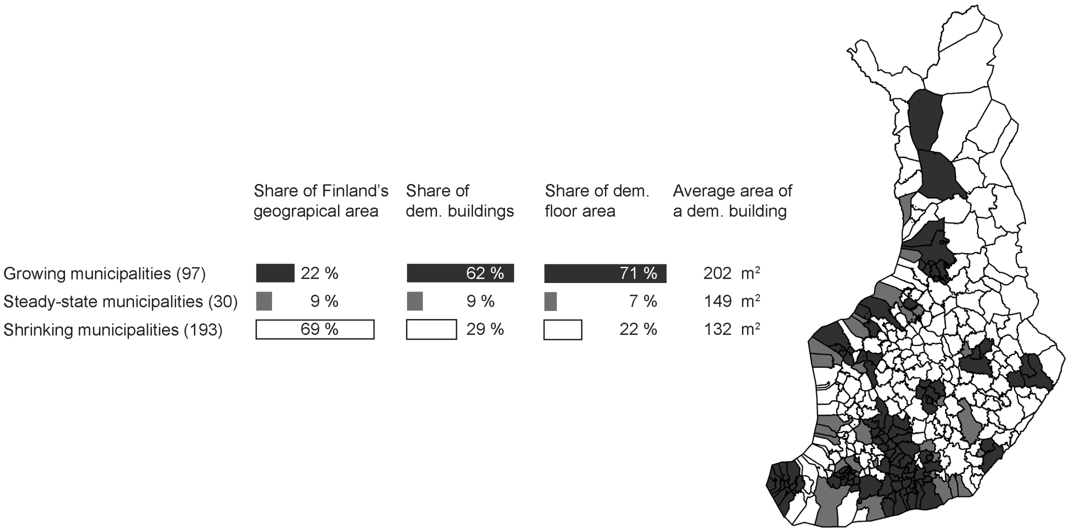
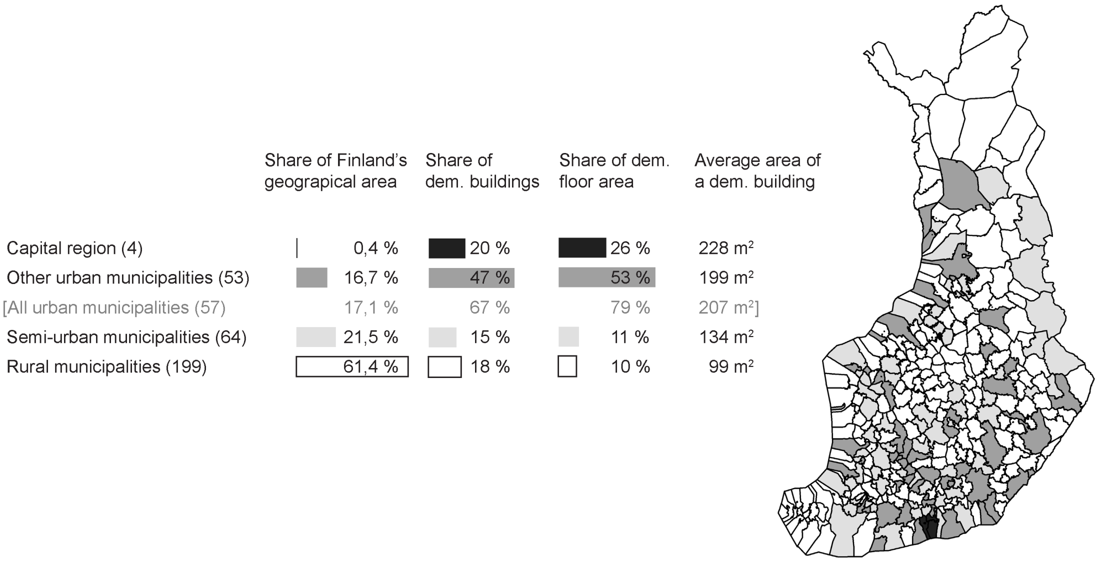


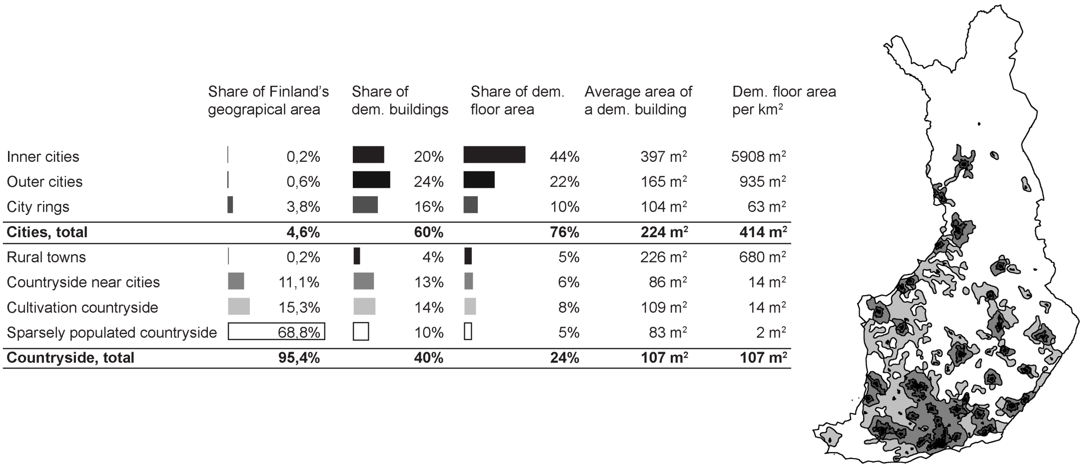
Figure 1. Shares of demolition in growing, shrinking and steady-state municipalities

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.



	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 m^2
Other urban municipalities (53)	16,7 %	47 %	53 %	199 m^2
[All urban municipalities (57)	17,1 %	67 %	79 %	207 m^2]
Semi-urban municipalities (64)	21,5 %	15 %	11 %	134 m^2
Rural municipalities (199)	61,4 %	18 %	10 %	99 m^2

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 km^2
Inner cities	0,2%	20%	44%	397 m^2	5908 m^2
Outer cities	0,6%	24%	22%	165 m^2	935 m^2
City rings	3,8%	16%	10%	104 m^2	63 m^2
Cities, total	**4,6%**	**60%**	**76%**	**224 m^2**	**414 m^2**
Rural towns	0,2%	4%	5%	226 m^2	680 m^2
Countryside near cities	11,1%	13%	6%	86 m^2	14 m^2
Cultivation countryside	15,3%	14%	8%	109 m^2	14 m^2
Sparsely populated countryside	68,8%	10%	5%	83 m^2	2 m^2
Countryside, total	**95,4%**	**40%**	**24%**	**107 m^2**	**107 m^2**

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

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, and it can be assumed that their demolitions are often connected (when a plot is cleared).

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 (35%) 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.

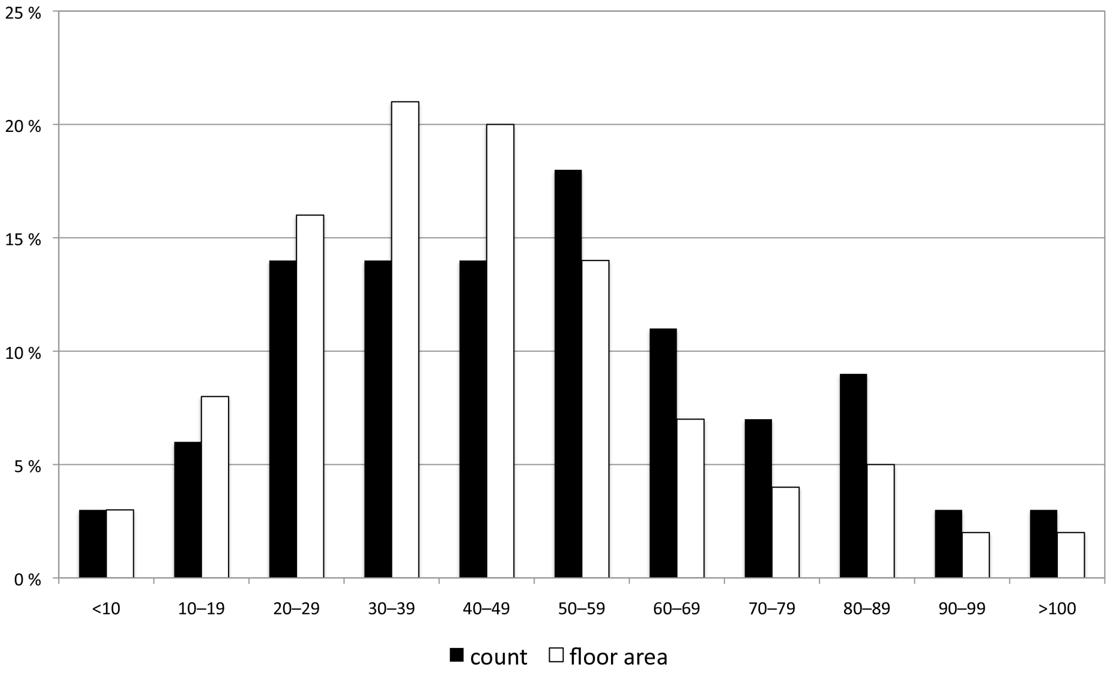


Figure 4. Shares of count and area of all buildings by age at the time of demolition

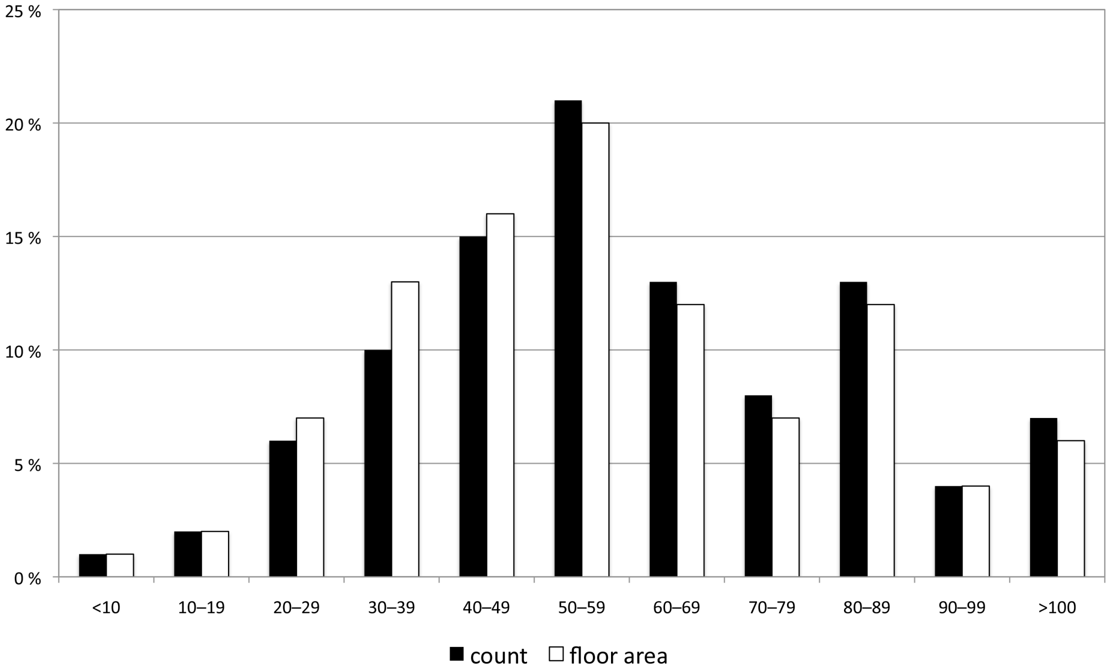


Figure 5. Shares of count and area of RB by age at the time of demolition

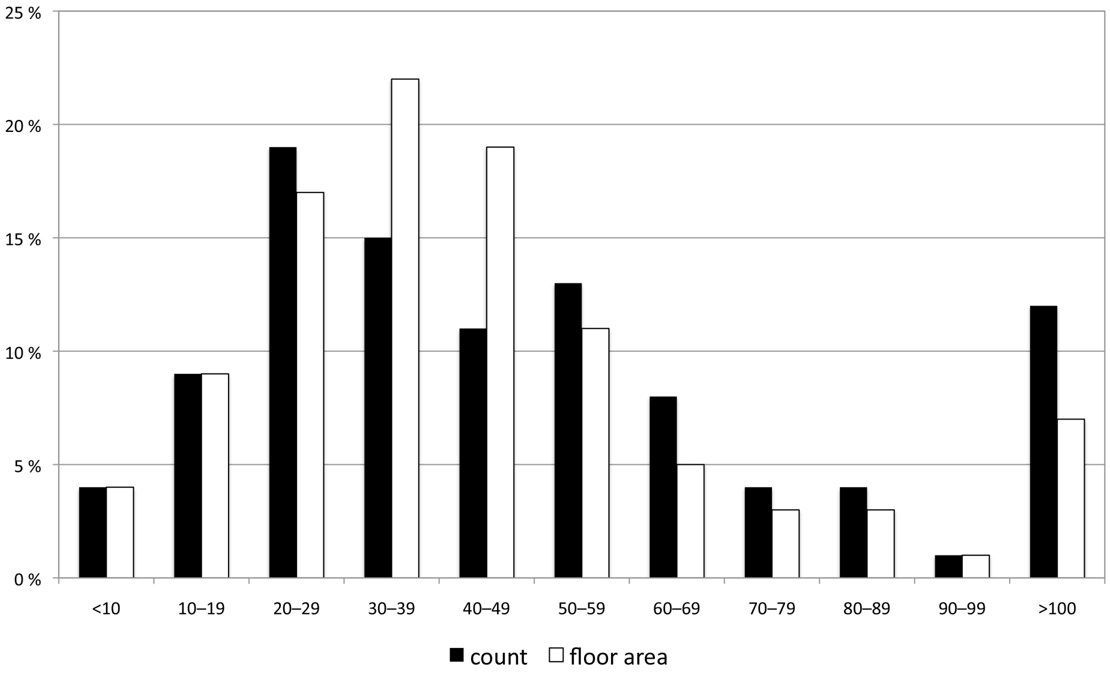


Figure 6. Shares of count and area of NRB by age at the time of demolition

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 aforementioned 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 indeed 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 (see Figure 4), 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.

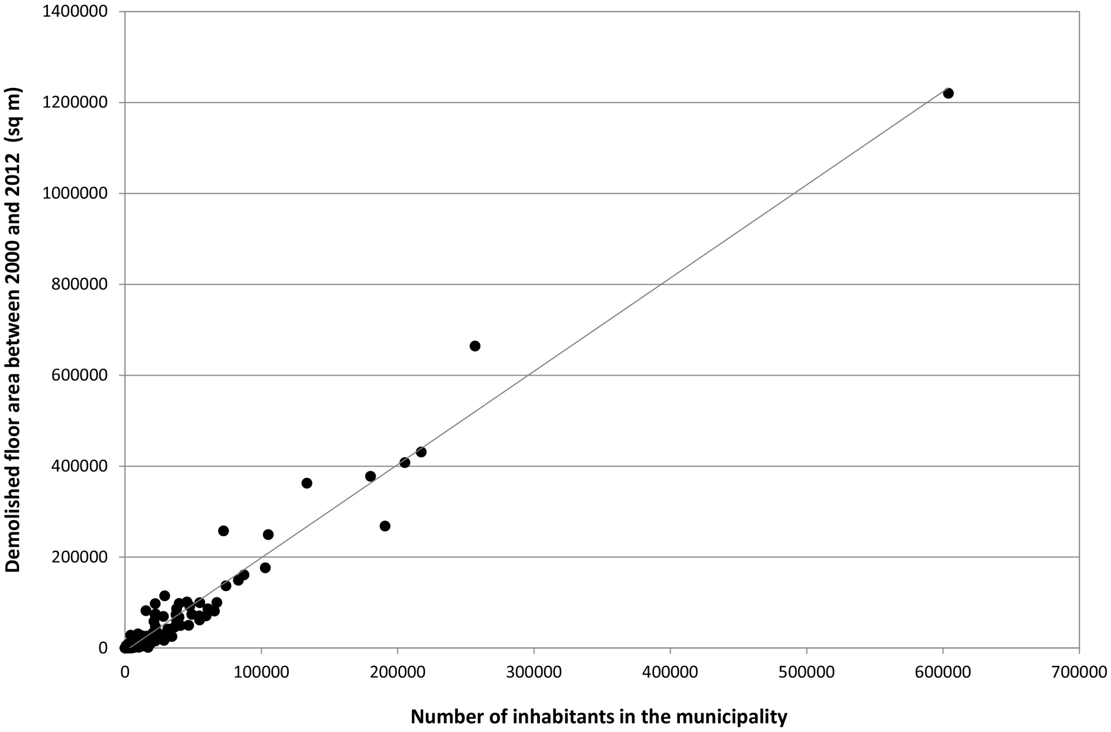


Figure 7. Number of inhabitants in municipality by demolished floor area

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 Sereda's argument (1978, as quoted in Holck Sandberg et al., 2014) 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) 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 that represented only 5% of all plots that had undertaken demolition. Growth centers 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 centers 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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