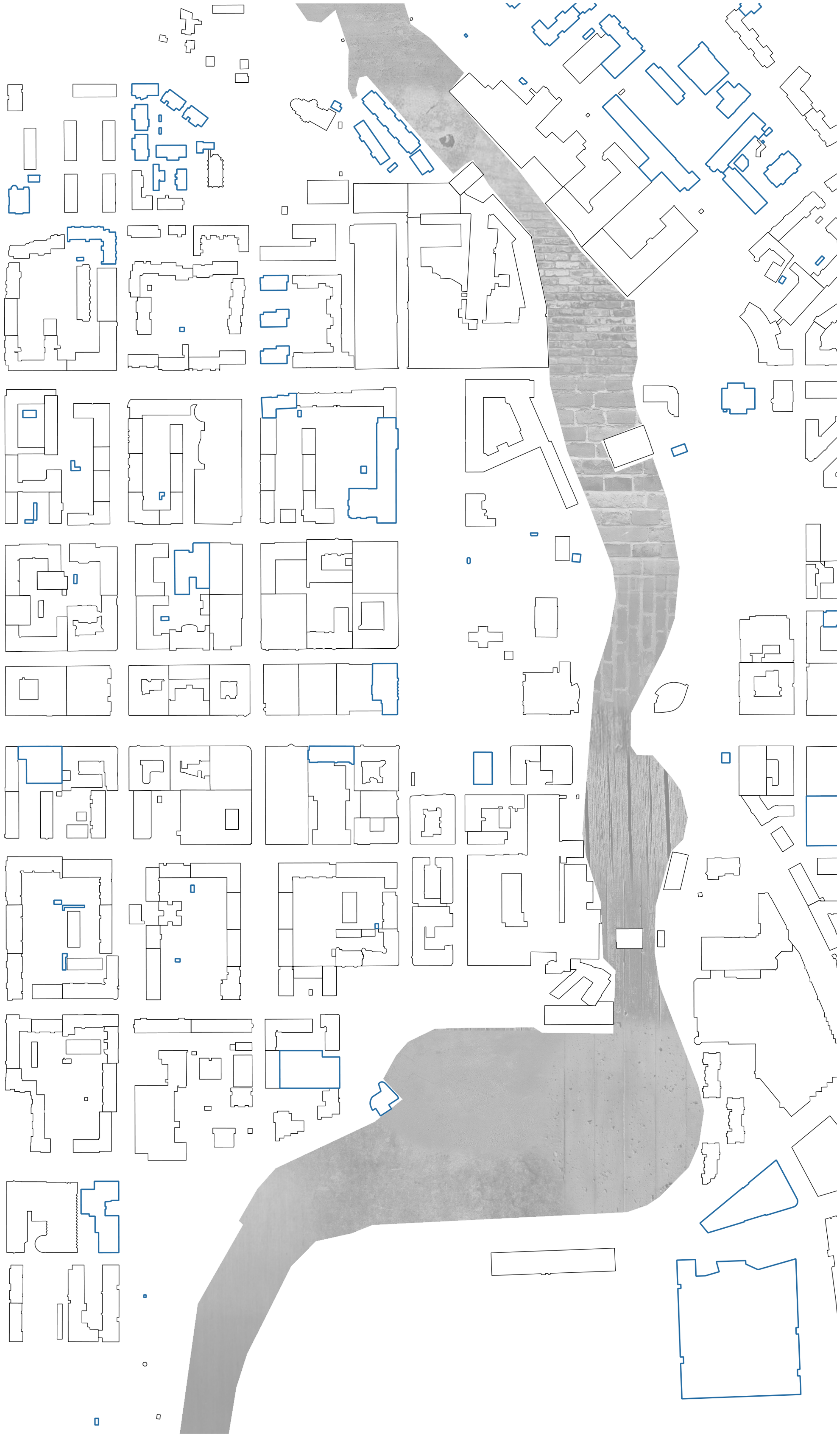
Tampere Urban Mine

An Analysis of Building Stock, Construction and Demolition 2000 - 2018



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Faculty of Built Environment, Department of Architecture
Master‘s Thesis
October 2020

I would like to express my gratitude to my supervisor Dr Satu Huuhka and Assistant Professor Dr Sofie Pelsmakers who have guided me patiently through the process of my thesis and I thank them for their honest, kind and professional feedback. Their expertise, determination and commitment are a great source of inspiration for me.

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Mein Dank geht auch an Elina Luotonen, welche, in Zeiten von Zweifel, immer eine große mentale und professionelle Unterstützung für mich war.

Abstract

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As embodied energy and emissions of buildings and construction materials start to move into the focus of attention, planners and urban decision makers look for ways to shift towards a more sustainable management of the building stock, construction and demolition. In this study, the urban building and material stock and flows of the Finnish city of Tampere were analysed, in order to identify the extent of and drivers behind demolition and construction. In summary of these findings, it seems that buildings often get demolished and replaced due to functional and spatial obsolescence, while large scale demolition often occurs after a relatively short building lifespan. Based on these findings and the circular economy framework, a catalogue of measures was created in order to aid the city developing an action plan to achieve its self-set goal of becoming carbon neutral by 2030.

Keywords: low-carbon built environment, buildings, construction, embodied emission, circular economy, urban mining, material flows, circular design

The originality of this thesis has been checked using the Turnitin OriginalityCheck service.

Preface

The study part of this work was funded by and conducted in the course of the CircHubs project. The work, which has been carried out between March and September 2019, has been transferred into a research paper which is currently under review (Huuhka & Kolkwitz, 2020). Dr Satu Huuhka has taken on the supervision and has guided me and our work through the process of scientific working.

In 2020, the research work has been transferred into this Master’s Thesis. Findings and results are partly based on the previously mentioned work and partly expanded through further analysis. The discussion part is an entire novelty which has been created as an individual work. Occasional feedback by thesis supervisors Dr Satu Huuhka and Assistant Professor Dr Sofie Pelsmakers have been the sole external contribution.

Tampere, 27. October 2020

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INTRODUCTION

The increased amount of carbon dioxide in the world's atmosphere and the resulting impacts of a changing climate are known to be one of today's greatest challenges for humankind. Not to mention the devastating consequences for global environment, biodiversity and the negative impacts on social equality and fairness, especially Nordic countries like Finland are expected to face hotter summers and milder and wetter winters, with direct effects on human health (SYKE Finnish Environment Institute, n.a.). The constant increase in greenhouse gas emissions (IPCC, 2018) calls for immediate and drastic actions for an effective climate change mitigation.

In the heart of the problem lies the wastefulness of current economic systems. For the longest time of its existence, humankind has imagined the earth to be a limitless plane with an unknown frontier and infinite hideouts to escape to as soon as things get too difficult. Humanity's "reckless, exploitive, romantic and violent [mis] behaviour" is what Kenneth E. Boulding (1966) identified as the underlying traits of, what he called, the "cowboy economy". Over several thousands of years, the idea of limitlessness has caused mass extinction of countless species, irreparable damage to ecosystems and the irreversible transformation of whole landscapes. With the realization that the earth is indeed a spherical system starts to arise an understanding for the impact of human behaviour. Today's wasteful behaviour with fossil fuels and the enormous amounts of greenhouse gas emissions, eventually resulting in a changing climate, however, will not only cause irreparable damage but impacts the whole globe and everything living on it. There is no other place to escape to.

On this earth, buildings provide shelter, they give comfort through heating or cooling down the spaces, people live, dwell and work in, providing fresh air, hot water, light and electricity to power devices and home appliances. The energy a building consumes while in use, is called 'operational energy'. Globally, residential buildings have caused one tenth of total greenhouse gas emissions in 2005 (Herzog, 2009). In 2018, Finnish households have been responsible for even almost one fifth of the country's total energy consumption (Statistics Finland, 2020).

Before buildings can be used, they need to be designed and built, the latter requires construction materials to be harvested, processed, transported and assembled on site. Additionally, the occasional replacement and maintenance and eventually the demolition of buildings consumes energy and produces carbon emissions (see figure 1.1). The energy that is used during these processes is often referred to as 'grey energy' or 'embodied energy'. In 2005, the production of cement, iron and steel caused almost one tenth of global greenhouse gas emissions (Herzog, 2009) which shows the critical linkage between embodied energy, the emissions that derive from it and their contribution to climate change.

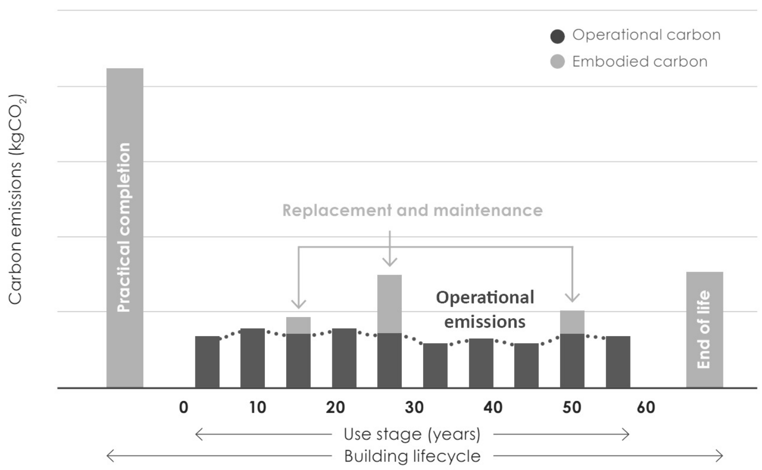


Figure 1.1: LETI - Embodied Carbon Primer

While the importance of operational energy is undisputed, the neglect of countable measures towards a reduction of the embodied energy made it the centre of attention in this work.

In addition to direct emissions, harvesting construction materials is responsible for more than one-third of global resource consumption (Klep, 2015). By 2030, it is expected that five billion people, which make 60% of the earth's population, will live in urban areas. Nearly half of them will live in homes, learn in schools, work in offices, workshops, factories and dwell in parks that do not yet exist (McDonough, 2017). Today, almost 85% of pollution in Northern European countries comes from urban areas. Until 2050, it is estimated that this value has climbed above 90% while global urban material consumption is likely to increase from around 40 billion tonnes in 2010 to around 90 billion tonnes in 2020 (Swilling, et al., 2018).

But it's not only the construction of buildings that puts pressure on the material market and the global environment. Between 2000 and 2012, 50 818 buildings were demolished in Finland (Huuhka, 2016). Those buildings accumulate to more than 9Mio m2 or over 40Mio m3 in demolition volume. The demolition waste gets downcycled or ends up in landfills where it loses most of its emotional, material and energy value that was used for harvesting, producing, transporting and assembling. As demolition often makes way for new construction, it also destroys the possibility of saving the materials and using them as a basis for new development. Urban areas, due to a growing population, are most likely to become hotspots of resource consumption and pollution, especially caused by conventional, energy- and resource-intensive construction and demolition methods.

Architectural design is – based on the individual approach – more or less centred around context, function and people. After construction, planners hand over the responsibility to the owner. While the maintenance of the building is also in their interest, the time and form of demolition is often chosen without considering the embodied material value of a building. In other words, while the phases of a building's design and life are covered by professional decision makers, the importance of the end-of-life-phase of a building is hardly ever recognized.

In one of her last works, Jane Jacobs proclaimed that Buildings Must Die (Jacobs & Cairns, 2014). Inside this philosophical statement, buildings are described as having a life and Jacobs claims that architects are the maker of it. However, the demolition of buildings is the rational component, that is hardly ever thought of. Even today, the end of life of a building is a taboo subject, while the process of creation is celebrated. The end of a building's life is seen as failure as the architectural self-image often derives from the classical notion of being a master builder who creates for eternity. The slow decay of Greek and Roman ruins is apotheosized while, in reality, buildings that were demolished in Finland between 2000 and 2012 have made it just over the 50 years threshold (Huuhka, 2016). What follows is dirty demolition work which doesn't consider any of the emotional or environmental values that go to waste along with its materials. A demolished building is turned into a pile of rubble. In the best case, this rubble gets downcycled but most often it is transported to landfills, along with 54% of construction and demolition waste (Ellen Macarthur Foundation, 2015). Those demolition practices show that the notion of earth being limitless has still not yet disappeared from current economic and design thinking. Despite its devastating effect on the built environment and hence, the planet, there is barely any knowledge about demolition and the reasons for it.

Today, the growth of urban areas is known to be one major driver, not only for new construction, but also for demolition. Between 2000 and 2012, 71% of demolished floor area in Finland was situated in growing municipalities such as Tampere (Huuhka, 2016). As future predictions for Tampere expect the city to continuously grow until at least 2040 (MDI, 2019), its building stock is going to grow accordingly which is expected to cause an increased rate of demolition.

1.1 Purpose of the study

A critical standpoint towards embodied energy, emissions of buildings and how these are related to construction and demolition creates the foundation for this thesis work. The operational energy of buildings on the other hand, will be rather treated as a side note. Having said that, sustainability goes even beyond these two aspects, and a single focus on carbon dioxide would leave out many important environmental and social aspects such as waste, water use, resource scarcity, biodiversity, equality and economic factors. The emission of carbon dioxide from construction is one large piece of that sustainability jigsaw puzzle. Hence, the overarching purpose of this work is to shed light on the importance of embodied energy and emissions in the context of climate change mitigation.

The following section gives insights in the economic model and some of its practical applications which considers the embodied energy and materials of buildings as valuable assets to be protected. The city of Tampere was chosen as the target of a case study in which the quantity of building stock, demolition and construction were analysed. The results were then combined in order to develop location specific strategies to shift from wasteful demolition and construction practices towards a more sustainable approach.

2

BACKGROUND

In 1966, Kenneth Boulding wrote that “the ethical thing to do is not to discount the future at all, that time-discounting is […] an illusion which the moral [hu]man should not tolerate.” After more than half a century, things don’t look too different from what he described as the “cowboy economy”. In the fifth edition of the UN’s Global Biodiversity Outlook report, none of the 20 objectives set out in 2010 have been fully met and only six are deemed to be achieved “partially” (UN News, 2020). Nevertheless, there are alternative ways to overcome the greatest challenge of our time.

In contrast to the “cowboy economy”, Boulding (1966) introduces the idea of a “spaceman economy” where the earth becomes a spaceship on which there are no unlimited reservoirs of anything. To visualize the difference between the two, the attitude towards consumption in the “cowboy economy” is seen as something positive and the more the better. In this linear system, consumer goods are manufactured from input virgin resources, used and eventually thrown away as output pollution. On the opposite, in the “spaceman economy”, the primary issue to deal with, is stock maintenance and technology that helps to mitigate the amount of production and consumption, which eventually, leads to a drastic reduction in virgin non-renewable resources and emissions from embodied energy. The idea of earth being a limited, circular system has sparked a variety of follow-up theories and studies which might have even had an influence on the emergence of the term “sustainability” in the classic Club of Rome report (Meadows, et al., 1972).

One of the most popular children of Boulding’s concept, is the idea of a Circular Economy. In 1982, the swiss architect Walter R. Stahel wrote a paper called “The Product Life Factor”. He proposes an economy based on a circular loop system, in order to reduce the wasteful behaviour with goods and energy to mitigate the negative impacts of our economy, without restricting its productivity. What used to be mere theory has been developed into a detailed framework that describes how we need to make things in order to decouple growth form the consumption of finite resources.

The Ellan Macarthur Foundation gives a good overview of the state of the art in Circular Economy (Ellen Macarthur Foundation, 2017). In contrast to the linear model of “take-make-waste”, it describes a closed economic system that partly mimics and adds into natural biological cycles. There are three underlying principles.

1. To Design Out Waste and Pollution questions the whole principle of end-of-life and biproducts. Since it was identified as the main misconception in a “cowboy economy”, the concept of waste must be overcome in order to keep a products potential of being a resource.

2. By Keeping Products and Materials in Use, we can make sure to preserve value in the form of energy, labour and materials.

3. Finally, Regeneration of Natural Systems means to use minimal non-renewable resources and the enhancement of renewable ones.

Those Circular Economy principles are widely based on the idea of a cradle-to-cradle system the way it was introduced by Michael Braungart and William McDonough. The authors point out the flaws in, what they call, “cradle to grave” and the “one size fits all” approach of a misconceived modernism. The lives of goods have become increasingly short while the inability of reuse, repair or often even maintain evidence that design focuses on satisfying producers rather than human or ecological health (Braungart & McDonough, 2008). Considering the global population trends, a less-harm approach won’t suffice. Producers’ and consumers’ behaviour must be understood in a context of natural ecosystems in which waste does not exist. The ultimate goals must be to make a positive impact by giving back more than taking away.

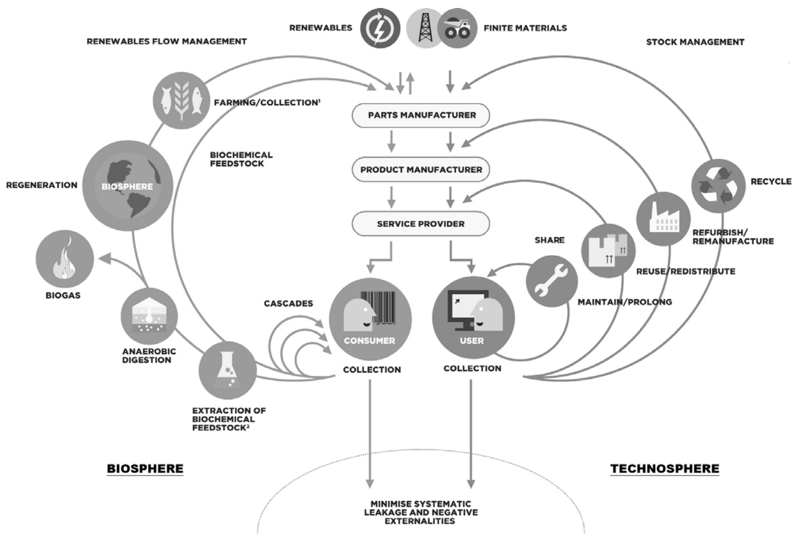


Figure 2.1: The Circular Economy by the Ellen Macarthur Foundation

In the Circular Economy model, renewable and finite resources enter a system of biological (biosphere) and technological (Technosphere) cycles. After going through one (or preferably several) use cycles, biological materials safely re-enter the natural world where they can decompose, returning nutrients to the environment. Technical materials, however, cannot do that. Synthetic materials such as metals, plastics and chemicals need to cycle continuously through the system and maintain their highest value for the longest possible time, as seen in the circles on the right (see figure 2.1). Those materials which used to be waste, i.e. output get turned back into a resource, i.e. input.

In the context of buildings, Circular Economy means to look at construction materials and discover ways of how their intrinsic value can be maintained for as long as possible. Demolition on the other hand, poses a massive threat for buildings which needs to be avoided if possible. In order to do so, it is crucial to first understand its underlying mechanisms and the most important factors which have an influence on the decision-making process.

The buildings that are appreciated age gracefully. Some buildings become better and more valuable, the older they get. Other buildings are deemed to lose their value over time and eventually get demolished. Today, demolition is often justified with obsolescence of buildings but even though all buildings age, not all of them become obsolete.

Obsolescence is a rather modern term and the idea of architectural depreciation came up in the late nineteenth-century America as a product of insurance policies and estimates on the longevity of buildings. Before 1900, the idea of a building becoming obsolete has been absent from the western architectural mindset, while buildings and their embodied values were expected to last for generations (Abramson, 2016). The Oxford Online Dictionary defines obsolescence as "the state of becoming old-fashioned and no longer useful" and architectural researchers usually present obsolescence as the divergence over time between declining performance and rising expectations. Probably the most common concept of obsolescence was developed by Thomsen and van der Flier who claim that "obsolescence of building stocks[…], is broadly defined […] as a process of declining performance resulting in the end of the service life" (Thomsen & van der Flier, 2011). Unlike the overall understanding of obsolescence, which is almost treated like a synonym for the physical condition of a building, the term describes a more holistic condition based on a variety of factors that eventually have an impact on the longevity of a building. These factors are usually strongly connected with economic value, regulations and market forces but also function, location, environment and fashion are part of it. In more detail, Thomsen and van der Flier (2011) distinguish between location (exogenous) and building (endogenous) obsolescence (see figure 2.2), while they discovered that – especially for buildings – behavioural aspects are usually more decisive than actual physical properties.

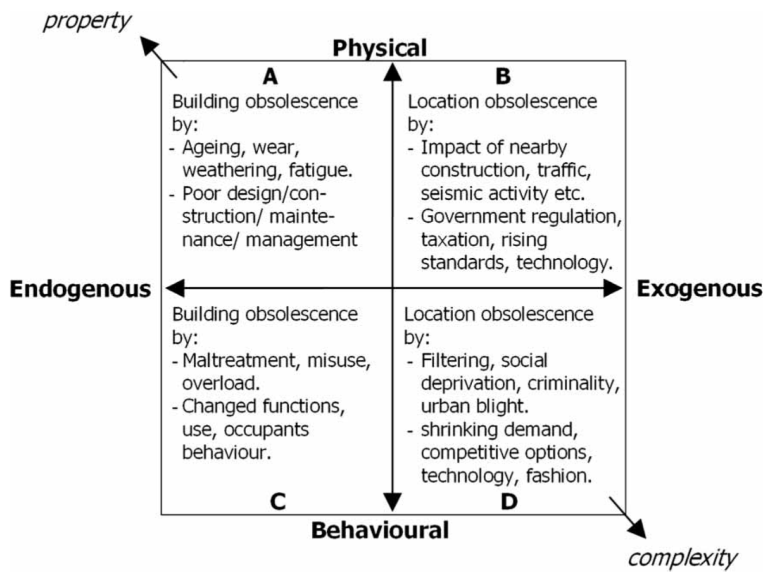


Figure 2.2: Conceptual model of obsolescence according to Thomsen and van der Flier (2011)

The physical condition of a building and its construction materials is often considered to be the main reason for the demolition of a building, which is however, just in very few cases true. Actual knowledge about the final decision making is scarce and fragmented. In a study in the Netherlands, it was found out that over 60% of demolition was motivated by functional or structural obsolescence and a similar study by the Athena Institute of 227 buildings in Minnesota, USA, showed that only one third of the buildings were demolished due to decay. Often, the motivation behind demolition is biased by prejudice about the benefits of renewal compared to new construction, while empirical data about demolition motives in the privately owned stock are almost non-existent (Thomsen & van der Flier, 2011). Often, obsolescence is seen as the tipping point that inevitably leads to the demolition of a building which, mistakenly, leaves out its series of alternatives. Building obsolescence should be rather seen as a condition and owners decide which actions are most adequate in that situation. Indeed, demolition is one way, but it discards the variety of options that might have been more sensible through refurbishment.

The actual correlation between obsolescence and demolition is often biased and not sufficiently covered by research. Nevertheless, there is an undeniable connection and obsolescence poses a threat for the value of buildings and their construction materials while architects, planners and building owners have a responsibility to come up with a way to minimize those risks. The following principle questions how buildings are often mistakenly looked at as one coherent entity. The concept of buildings in layers adds nicely to the idea of building obsolescence as it introduces the idea of different life expectancies (based on different aspects of obsolescence) of different parts of a building.

“Our basic argument is that there isn’t such thing as a building. A building properly conceived is several layers of longevity of built components.”
(Frank Duffy)

Before applying circular design principles, architects need to rethink the way of looking at buildings. Instead of being a single whole, buildings have several layers of longevity which means that before their end of life, different parts usually go through several stages of transformation. The American writer Stewart Brand has developed Frank Duffy’s concept of four layers into what he called the Shearing Layers of Change (Brand, 1995) which describe different layers of buildings and different life expectancies (see figure 2.3). The first of these six layers is the Site or a building’s geographical location which usually doesn’t change at all. The Structure describes a building’s foundation and load-bearing properties which are, in most of the cases, too expensive to be changed. Brand states that the structure is the actual building, which has a life of up to 300 years, even though most of them don’t make it past 60 years. This leads to the Skin or façade of a building which has received increased attention in the past years when building performance has shifted further into the focus of attention. The Service layer is the organs of a building including communications and electrical wiring, plumbing, HVAC, etc. The Space plan or interior layout determines where (non-load-bearing) walls, ceilings and floors separate spaces. Finally, the Stuff inside buildings such as furniture, decoration, appliances, etc. are the most frequently changed layer, usually determined by the users.

Thinking in layers helps architects to unravel the complexity of the design issue by approaching each layer from a slightly different angle. Knowing that the lifespan of the interior space plan is usually below the overall structural life expectancy, encourages to design a loadbearing system which allows to make changes as flexibly as possible. The same applies to services which need to be brought to their latest standards approximately every 7 to 15 years. On the other hand, the stuff or interior, known to be the most short-lived element inside a building, needs to be treated with extra care to avoid being thrown away every couple of years, while the skin, being constantly stressed, needs to be extra durable against external impact. Designing in layers and keeping them separable allows the structure to be retained and the building will be easier to disassemble so that its components can be reused, remanufactured or recycled.

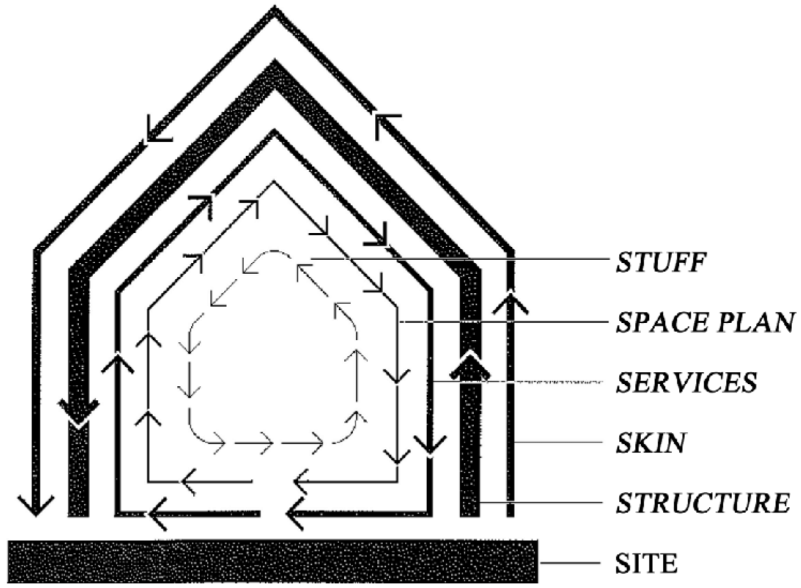


Figure 2.3: The Shearing Layers of Change according to Brand (1995)

Eventually, the Circular Economy becomes a design task. In this stage, important decisions are made which have an influence on the circular potential of goods. Once inappropriately designed, it can become hard to undo it. Nevertheless, the full potential of Circular Economy principles in the built environment go beyond the possibilities and commitment of the individual. It requires a systematic change and innovations in technology and policies while current economic, financial and business models need to adapt. The British architect, author and environmental activist Duncan Baker-Brown argues that “the challenge of getting the construction sector to change isn’t about encouraging policy makers […], it’s about getting architects, civil engineers […] and potential users to buy into the circular economy and understand the benefits” (Baker-Brown, 2017). The following chapters introduce (architectural) design principles which accompany the cycles of a circular economy (see figure 2.1).

2.1 Maintenance

One of the goals of sustainability is to preserve the intrinsic value of buildings, save them from obsolescence and make them durable. This must not be misunderstood with building fortresses or bunkers that may physically endure but fail to adapt to new circumstances. It rather aims for maintaining the value of buildings and materials for as long as possible.

Maintenance of buildings means to keep them in a good shape which includes preventing buildings from deterioration and to act preventively, in order to avoid obsolescence. Most people who buy a new car know the struggle of not being able to fix it themselves without any extra effort. Manufacturers of building components will have to make products that can be easily maintained. For example, the use of modular, standardised and universally applicable components is an easy way to ease the effort of replacing, i.e. repairing. Moreover, maintenance needs to be easy enough for building operators to do it themselves. Low dependency on tools, easy handling and an easy access to critical building parts are very important. Finally, materials need to be chosen in line with the building context. Poor detailing and a lack of knowledge about the material characteristics will cause an unnecessarily high amount of maintenance effort (Mulder, et al., 2012).

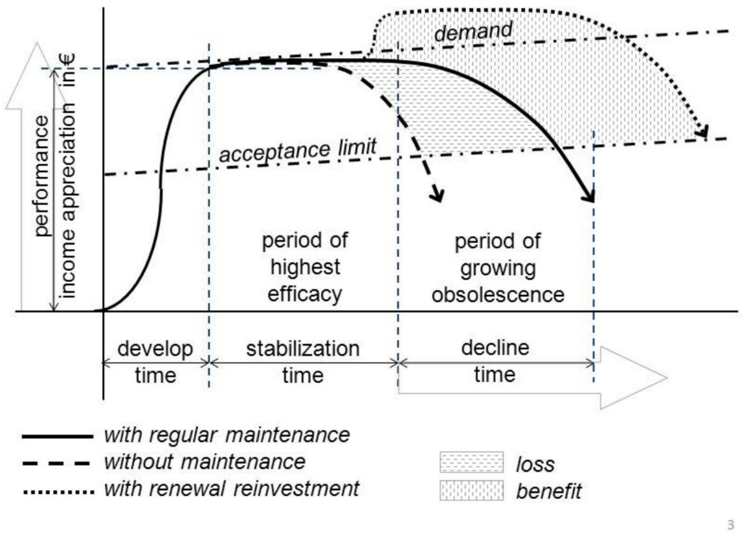


Figure 2.4: Obsolescence and service life according to Thomsen & van der Flier (2011)

In the past, aesthetics and sustainability appeared to be two controversial mindsets and the latter has been widely neglected by the architectural elite. In fact, buildings can be highly sustainable but unattractive, while in cases where architects achieve beautiful ecodesign, the aesthetics of that building are rarely related with what makes it sustainable (Hosey, 2012). The architect and writer Lance Hosey (2012) argues however, that good design has an undeniable impact on the endurance or survival of a building which affects its sustainable value. Today, some architecture firms like to highlight the importance of good design and its influence on human behaviour. Supposedly, a well-designed building makes people feel attached to it. Affection creates a certain feeling of responsibility and hence a higher commitment for maintaining the building in such a state that made you appreciate it so much in the first place.

> “Permanence is not a matter of the materials you use. Permanence is whether people love your building.”
> (Shigeru Ban)

While existing buildings and their material value needs to be maintained, applying the same conservation standards as for protected historical buildings, would not be the appropriate solution. In fact, it would be counterproductive. Building maintenance must not result in preserving buildings in a certain state of condition. The value of buildings’ capability to adapt needs to be acknowledged as, too often, they get demolished without being identified as non-transformable. Preserving a certain building state also hampers measures in order to improve the building performance. Even though it must be said that retrofitting insulation material to a building façade is often a controversial solution, especially when considering the added up embodied energy. However, if properly applied, it may improve the thermal performance of a building significantly and reduce its energy consumption while in use.

Another aspect of maintenance adds to the design task of architects. Shared economy is an economic model based on sharing goods and services among a group of users beyond family and/ or household. It can be integrated in a building by planning additional spaces for shared facilities. Indeed, a reduced amount of home appliances means a reduced amount of embodied emissions. What goes beyond the skills of an architect directly concerns manufacturing companies. Changing to a business model where users rent a device from the manufacturers instead of buying it, encourages firms to invest in longevity of their products.

2.2 Reuse & Redistribution

The idea of buildings in layers has introduced architects to the idea of seeing buildings as transformative objectives with a heterogeneous layer structure. Historic residential buildings are a classic example. From their initial state of usage, where families often lived crammed together, to spacious apartments with inbuilt bathrooms, saunas and kitchens, floor plan layouts and interior were changing along with societal change. Usually, the only thing that has not changed over time is the building's location and its load-bearing structure. Existing buildings have a natural transformation potential which, in order to reduce the amount of demolition and to sustain the building stock, needs to be seized.

These aspects can be considered already during the design process. What makes buildings fit for functional changes? For what kind of eventualities do buildings have to be prepared and which ones can be taken into consideration while designing them? With the help of different future models including demographic and economic predictions, architects can develop transformation scenarios for which their buildings will be prepared for. These also include the spatial properties. After the Berlin wall has fallen, millions of Germans moved away from the East in order to seek their luck in the prosperous West. This mass migration caused a massive inflation in housing in the new states which could have resulted in an even more devastating wave of demolition if Germany would not have launched a serious of protective measures in order to save some of the buildings that were built in times of the GDR. Spatial adaptability needs to become an architectural agenda. Whether buildings need to be extended or shrunk is often unpredictable, nevertheless, buildings need to be prepared for either scenario in order to avoid demolition due to unsuitable spatial or functional requirements.

2.3 Disassembly

The disassembly and component harvesting of buildings is probably one of the least regularly practiced stages in circular economy. Here, buildings components, incl. wall panels, slabs, columns, and so forth, are getting dismantled and harvested with the intention to reuse them for new construction. Especially building stocks with a high level of standardized building components, such as precast concrete elements, have a high potential for developing standard procedures for dismantling and reusing harvested building components. But also, stocks with (seemingly) less repetitive construction techniques have a potential for reusing building elements which is too often overlooked.

The reusability of building components is one crucial aspect during the design of a building. In order to avoid waste due to the inability of a building component to be reused, they need to be manufactured to be dismantled and reused for new construction. Certain element properties affect the potential of reuse. Prestressed concrete elements for example, are difficult to dismantle and to store since they are specifically designed to be exposed to constant pressure. Elements with standardized dimensions and joint techniques that simplify disassembly on the other hand, often have a good chance to become part of a new building.

Generally, the existing stock needs to be acknowledged as a massive building component resource. Only then, we can start to retrieve the potential of buildings as material banks.

2.4 Up- & Recycling

Often overlooked, upcycling is – by definition – one of the most valuable tools that can be applied in a circular economy. As the goals of upcycling are not only maintaining, but uplifting the value of a material, it is, in practice, most often used in developing countries that face an abundance of certain waste products and scarcity of natural resources. Discarded tyres find new function in a garden bed, empty glass bottles are used for the construction of wall elements and old shipping containers are used for building new homes.

The most common and least favourable stage of applying the circular economy is recycling. In comparison with reused elements, recycled materials go through a bigger number of manufacturing processes in order to give them a new life.

Again, the built environment is an excellent urban mine which contains a massive amount of construction materials, ready to be recycled. In practice though, recycling often means downcycling. For example, only in very few cases, concrete aggregates are reused for new concrete. Instead, the crushed concrete often gets used as a road construction material of much lower quality, which means that the amount of labour and energy that was used to produce it in the first place, get lost. A much better recycling practice would mean to reuse the harvested building components for at least the same purpose as its initial use.

Already in the design of building materials, the aspects of recyclability without downcycling need to be considered. After a building component has reached is end of life, it must be easy to take apart, especially to separate those materials that belong to the biological cycle from those materials of the Technosphere. Furthermore, materials of the technical cycle like plastics or metals, need to be separable in order to retain their material value. In practice, materials of a high value are lost because they are bound to less valuable materials which make recycling, without downcycling, impossible. One example is the modern way of manufacturing cross-laminated timber. While wood is an excellent natural and often very sustainable resource, the use of toxic adhesives prevents the component to fully decompose and return into biological cycles without leaving behind unnatural remains of chemicals. Another example is the use of bricks. Since the 1960s, construction firms have started to use cement-based mortar for brick construction. The increased strength of the joints made it more difficult and hence, unprofitable to disassemble walls without destroying the bricks. Manufacturers need to rethink this highly wasteful use of materials while architects must prefer materials which can be easily recycled.

Classic examples of the potential of recycling can be found in old Romanesque buildings in Italy. Due to a shortage of construction materials, builders harvested components from ancient structures and skilfully embedded them in their new construction projects. Resource scarcity has been a common problem throughout history, recycling and reusing therefore, was a logical consequence. Today, exploitation of natural resources will eventually result in the same issues. Learning from historical recycling techniques can be a powerful tool, to reduce the pressure on natural resources.

2.5 Material Selection

Adding to aesthetical and physical property aspects, sustainability starts to influence the final decision on which materials are used for the construction of a building. At this point, it must be highlighted again, that the embodied energy or carbon of a building material is not the only sustainability criterium. The final material choice must also take aspects such as recyclability, thermal performance, impact on internal air quality, availability, aesthetics, longevity and costs into account in order to make a well-informed and holistic decision.

Based on the amount of embodied emissions (through harvesting, transportation, manufacturing and construction) reused components and recycled materials often are the smartest choice. Nevertheless, the longevity of materials plays an important role, which could mean that in some cases, more durable virgin construction materials might be the most sustainable way. The use of virgin materials needs to be considered very carefully based, not only on longevity, but also on recyclability, embodied carbon calculations which includes transportation but also whether it is biological and from a renewable resource. The use of natural materials, i.e. materials that can be brought back into biological cycles (given it is not irreversibly combining with a technical material), are often a more environmental-friendly choice, while technical materials need to be separable in order to retain the individual material value. Today, the majority of technical components is a mix of several materials with hundreds of different polymers and alloys. Those ‘monstrous hybrids’ (Braungart & McDonough, 2008) make reuse and especially recycling almost impossible which drastically shortens the material’s lifespan. In practice, aluminium and most plastics that are used for the construction of buildings, get mixed up and hence, lose their material value. Today, manufacturers start to produce materials which are fit for biological cycles and decompose and have a reduced amount of separable technical components. A variety of different standard labels consider different aspects of the environmental impact of construction materials and components. Probably closest to circular economy principles, the Cradle to Cradle Certified™ categorizes materials by material health, material reusability, embodied energy source, embodied carbon, water management and social fairness. The natureplus®-eco-label on the other hand, focuses on the protection of limited resources, sustainable virgin material extraction, resource- efficient manufacturing and longevity of materials. Whether or not these materials get used in a construction project, highly depends on architects and whether the aspects of circular material choices get implemented in the design of buildings.

Overall, the use of materials must be reduced. New industrial construction techniques do not only help to build more cost-efficiently but also reduce the waste generation by using prefabrication or 3D printing based on detailed structural models. These techniques can become powerful tools to further maximize a building element’s performance and minimize its material intensity.

2.6 Studying the urban mine

Urban areas stock major extents of building materials including concrete, bricks, steel, copper, glass, etc. which consume large amounts of energy in manufacturing processes and generate a great quantity of demolition waste (Tanikawa, et al., 2015). With an increase in global population, comes an increase in urban material stocks which – if current economic processes do not change – will consume even more energy and produce even more waste. Furthermore, these stocks are not static; new construction (inflow) and demolition (outflow) create material flows which equally depend on and impact urban metabolism processes. With the help of Material Flow Analysis (MFA), these processes can be studied (see figure 2.5) and used to create efficient sustainable material and building management strategies (Hendriks, et al., 2000; Kohler & Hassler, 2002). To date, there is a series of research that approaches MFA from different kinds of methodological angles, time and regional scales but also motivations behind research varies in many cases. The combination of heavy data and information on building location allows researchers to make more site-specific discoveries with Geographical Information Systems (GIS). Through the four-dimensional Geographical Information System (4d-GIS) method, the time aspect was added to the urban flow analysis (Tanikawa & Hashimoto, 2009). The top-down approach focuses on the study of flows with less consideration of the internal processes of a system (Augiseau & Barles, 2016). A bottom-up analysis on the other hand, is usually a more precise way to analyse stocks and flows, often with the help of specific databanks, divided by attributes like age, function, etc. (Schiller, et al., 2017). Both approaches can be either static or dynamic. While the static model has a shorter study period of usually one year, a longer period is studied in the dynamic model (Augiseau & Barles, 2016). As previous MFAs have rather focused on the inputs and outputs, taking the urban stock into consideration is an important factor for identifying the opportunities in reuse (Gorgolweski, 2017).

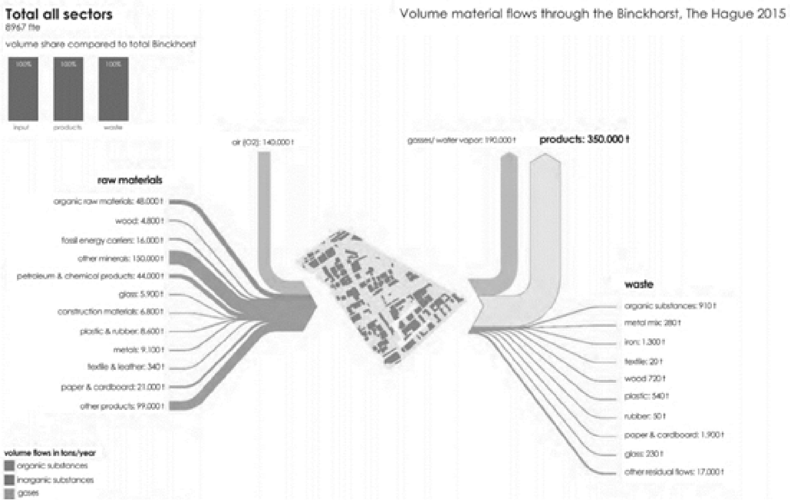


Figure 2.5: An example of a top-down material flow analysis in The Hague by Superuse Studios

Measures to make the building industry more circular highly depend on the local conditions and therefore, without a true scientific background, interventions cannot be optimally designed (Cartwright, et al., 2020 (unpublished report)). The purpose of this study is to bridge this knowledge gap. By analysing in- and outflow of buildings and change of building stock in Tampere can help to identify the underlying urban metabolism, i.e. the mechanism and behaviour that encourage construction and demolition. The goals are to provide planners and decision makers with information that help them to stir the local building industry towards more sustainable approaches by developing a preliminary framework of actions. In the long term, Tampere could become a role model for other cities to apply similar principles through similar studies.

The following part introduces the reader to the scientific background, methodology and material that was analysed in the subsequent study. A quantitative and spatial analysis of the building stock, construction (inflow), demolition (outflow) and comparison between construction and demolition was conducted in order to answer the following research questions:

What are size and spatial distribution of demolition and new construction in Tampere and how are they related?

What are spatial and quantitative patterns of demolition and new construction and how are they related?

What are the main drivers for demolition and new construction?

How do the patterns in demolition and new construction potentially affect the building stock?

The key findings of this study were condensed and, combined with the principles of Circular Economy, a catalogue of measures was developed that gives more detailed, evidence-based instructions on how to apply the findings.

3

RESEARCH DESIGN

3.1 Studied Material

The research data was provided by the city of Tampere and consists of two distinct sets: the first one is an extract of the National Building and Dwelling Register which is maintained by the Finnish Population Register, the second one gets maintained by local authorities in Tampere. Both datasets contain information on existing and demolished buildings in Tampere and are categorised by a series of attributes which give information on the building location, type, year of construction or demolition, main construction material, floor area and some more which were deemed less relevant for this study.

Building ID	Building type	Year of construc tion	Flo or are a	Construc tion material	Year of demolit ion	coordin ate
1001051 62A	Detache d house	2001	189	Wood		XY
1020458 15B	Block of flats	1968	275 0	Concrete	2008	XY
1044914 09L	Holiday cottage	1958	65	Wood		XY
1000032 23X	Detache d house	1999	120	Wood		XY
1010539 39I	Public building	2013	140 0	Brick		XY
1001438	Wareho	1987	350	Steel	2013	XY

Table 3.1: a simplified representation of data tables used for the analysis

Due to numerous errors and shortcomings in both data sets, the data that was eventually used in the study went through several processes of matching, combining and eliminating records. The quality of records for existing and demolished buildings varied significantly, mainly due to the fact that demolished buildings are usually older and hence, receive less attention and therefore, often lack information. This also caused the data to be handled differently in this study. The treatment of demolished buildings (as explained in the following paragraph) turned out to be so time intensive that a slightly less comprehensive approach was chosen for the data of existing buildings (as explained in the paragraph after that).

The national data set (BDR) contains in total 4052 and the local data 8536 records for demolished buildings or structures. It was known from a previous study that the quality of the data improves after the year 2000 (Huuhka & Lahdensivu, 2016), so it was decided to start the inquiry from 2000. The research started in early 2019, so 2018 was set as the backstop for the investigation. Since both datasets had numerous errors, a series of compensation tasks were performed in order to achieve a sound data base (see Appendix Data Processing). In total, 43 637 records were used for existing buildings and 3 134 records for demolished buildings.

Both data sets contain 74 different building types which each have an individual three-digit building type number. In order to make the building types easier accessible, these building types were categorized in 13 building type groups which were mainly used during the analysis (see table 3.2). In some preliminary analysis, a rougher distinction between residential buildings (RB) and non-residential buildings (NRB) was made.

	Building Type Group
Residential buildings	Detached houses
	Row houses (attached houses)
	Blocks of flats
	Holiday cottages
Non-residential buildings	Dormitories
	Utility buildings
	Commercial & office buildings
	Public buildings
	Warehouses
	Industrial buildings
	Agricultural buildings
	Transport buildings
	Other buildings

Table 3.2: Building types

3.2 Study Method

Based on the definition by Augiseau and Barles (2016), the study was performed through a bottom-up material flow analysis. As the data was found to be most reliable for buildings built and demolished after the year 2000, the study of in- and outflows focused on the period between 2000 and 2018. Given the data, single buildings could be summarized and quantified in groups in order to create an overall image of existing buildings (stock), new construction (inflow) and demolition (outflow). For the quantitative analysis, the buildings were analysed by building type, year of construction, year of demolition and construction material. These were then either quantified by the number of buildings or the amount of total floor area.

The buildings' construction materials only takes the main material of the load-bearing structure into consideration and leaves out materials from other building layers completely. In order to make an assumption of the total number and floor area of buildings' construction materials, missing information derived from a compensation based on the relative numbers and material composition of those buildings which have information. It is important to mention that mainly non-residential buildings, including holiday cottages, were target of this compensation work. While detached houses, blocks of flats and row houses have reliable information in 98 – 99% of the cases, non-residential buildings tend to have smaller numbers between 92% (public buildings) to as little as 23 % (agricultural buildings) and 14% (other buildings). On the other hand, looking at the floor area of these buildings, there is usually a very high percentage that is covered by the data. Utility buildings (77,5%) and other buildings (78,5%) are the exception, after that come transport buildings that have reliable data for 90% of the floor area and the remaining building types vary between 97% and 100%.

In the later stage of the study, a geographical analysis provided information for the location of buildings which could then be combined to the previously found categories from the quantitative study. By merging single buildings into a grid of 250 x 250 metres, the spatial study on the urban level became visually more accessible. Each square contains all the buildings that are located inside of it with regards to their number, function and total floor area. This way, clusters of demolition and construction were identified and quantified in order to get an overall image of spatial patterns such as greenfield development or urban densification. In combination with the years of construction and demolition, the spatial analysis helped to identify replacement patterns where demolition was caused by new construction, i.e. changing land use needs. In order to get a deeper understanding of the spatial patterns, the data was paired with other sources of information such as Google Maps, historic aerial photographs, local detailed plans, masterplans and personal knowledge of the areas. Even though the spatial data covered the whole municipality of Tampere, the study focused on the urban area as the large majority of buildings and built floor area was located there.

4

STUDY RESULTS

4.1 Construction

An annual increase of over one percent makes Tampere one of the fastest growing municipalities in Finland (Statistics Finland, 2020). With an increase of approximately 3 000 residents per year, comes an increasing demand not only for living space, but also for public and commercial services.

Between 2000 and 2018, 8 317 buildings were erected which make a total of 4 431 604 square meters. As shown in graph 4.1.1, more than two thirds of these buildings are detached houses or utility buildings. However, these results look differently when it comes to the floor area: Blocks of flats make more than 45% of the total floor area, followed by detached houses (13%), commercial and office buildings (11%), public buildings (8%) and row houses (7%). In other words, detached houses and utility buildings add up to only 15% of newly constructed floor area while they are by far the most frequently built building type groups.

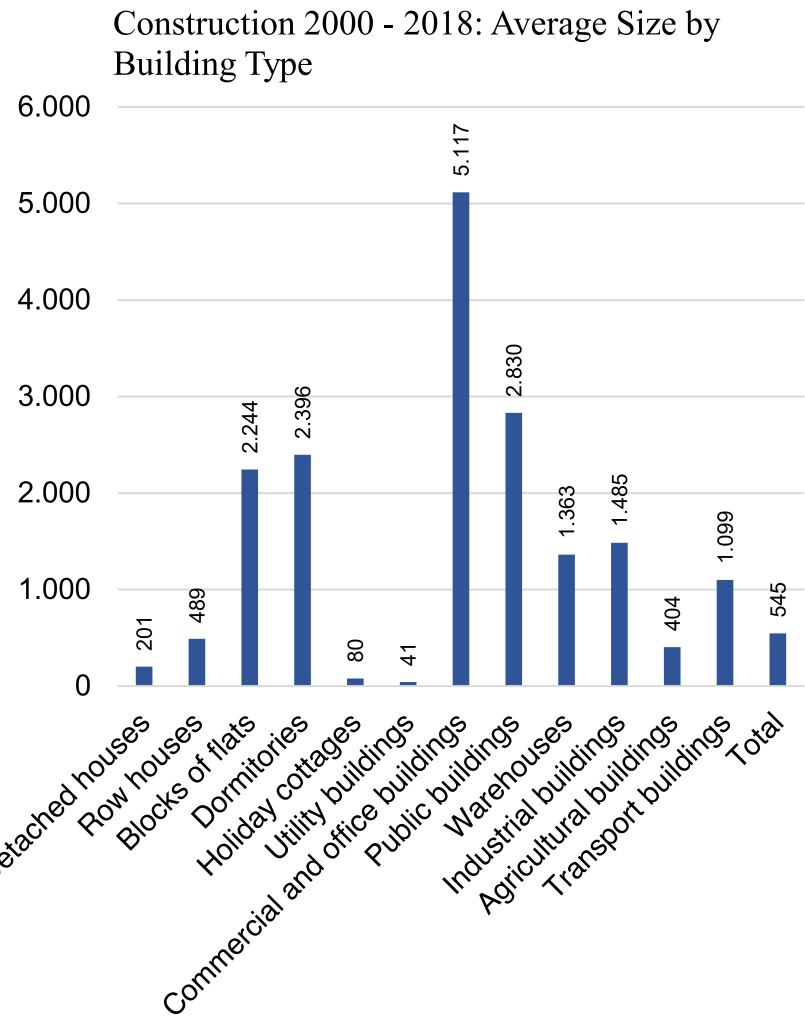
Interestingly, residential buildings accumulate to more than half of newly built floor area. With blocks of flats, a relatively homogenous building type group, a lot of materials enter the building stock. It may be most meaningful to start implementing circular principles for those buildings as they seem to have the biggest impact on material inflows. Developing circular design strategies for newly built blocks of flats, therefore, has a significant impact on the whole building and material stock. Nevertheless, other building types like commercial & office buildings, public buildings industrial buildings, etc. must follow.

Average size

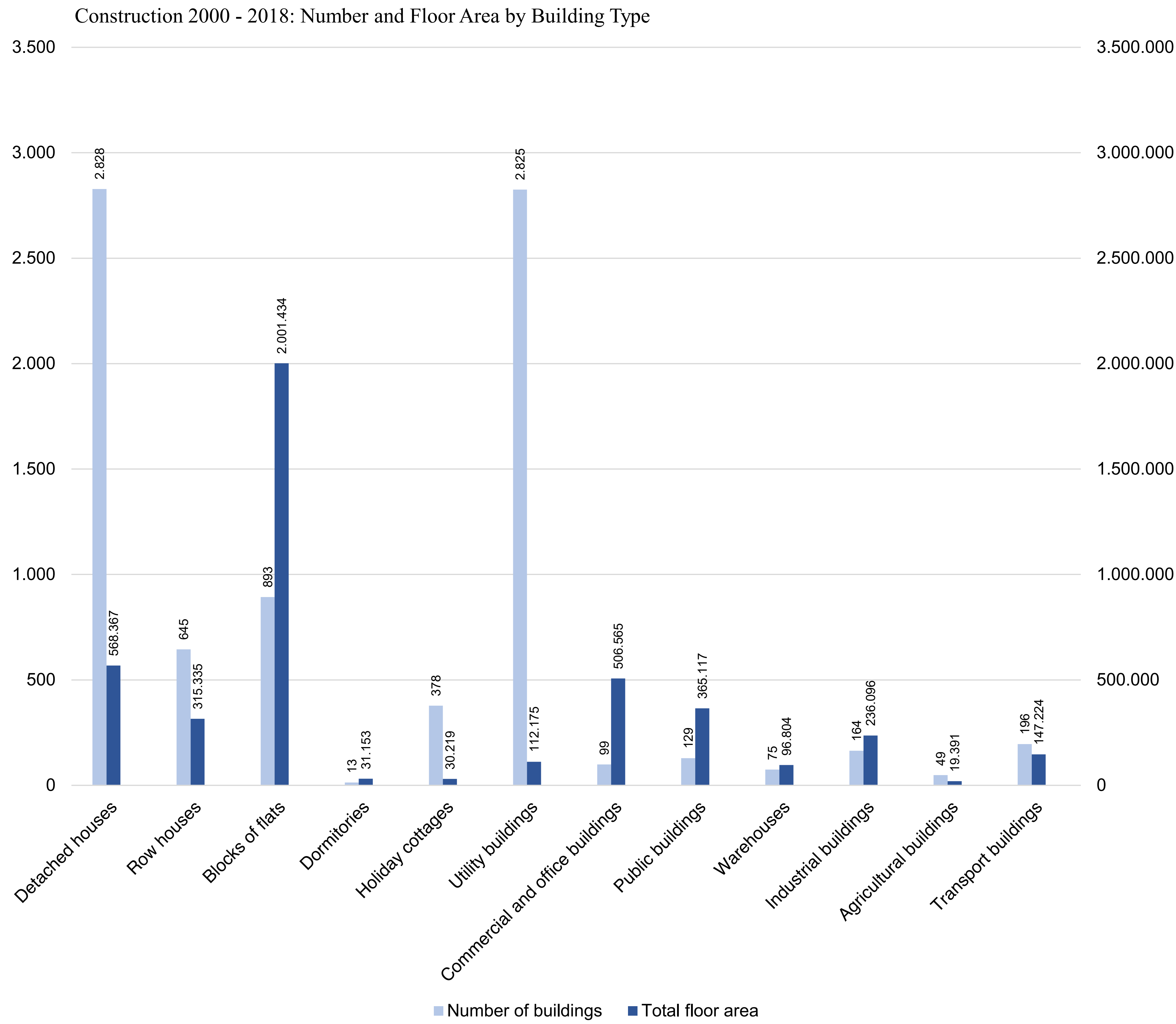
Graph 4.1.2 shows that commercial and office buildings are on average by far the largest newly constructed building type. Public buildings follow, dormitories and blocks of flats come after. On average, the size of each newly constructed building is 545 sqm. Utility buildings are the smallest buildings with as little as 41 sqm, other buildings and holiday cottages also lie significantly below the total average. Generally, the size differences between newly erected buildings is significant.

It appears that the material intensity of buildings partly corelates with its function. The larger a new building is, the more materials were harvested, processed, transport and assembled on site, i.e. added to the building and material stock. However, the average size of a building does not necessarily determine its material intensity. For this purpose, Material Intensity Coefficients (MICs) become invaluable.

Based on the large average size and overall impacts (see graph 4.1.1), it would be worthwhile looking more closely into the new construction of commercial & office, public and industrial buildings.



Graph 4.1.2: Average size of new buildings by building type



Graph 4.1.1: Construction of buildings by total numbers, total size and building type

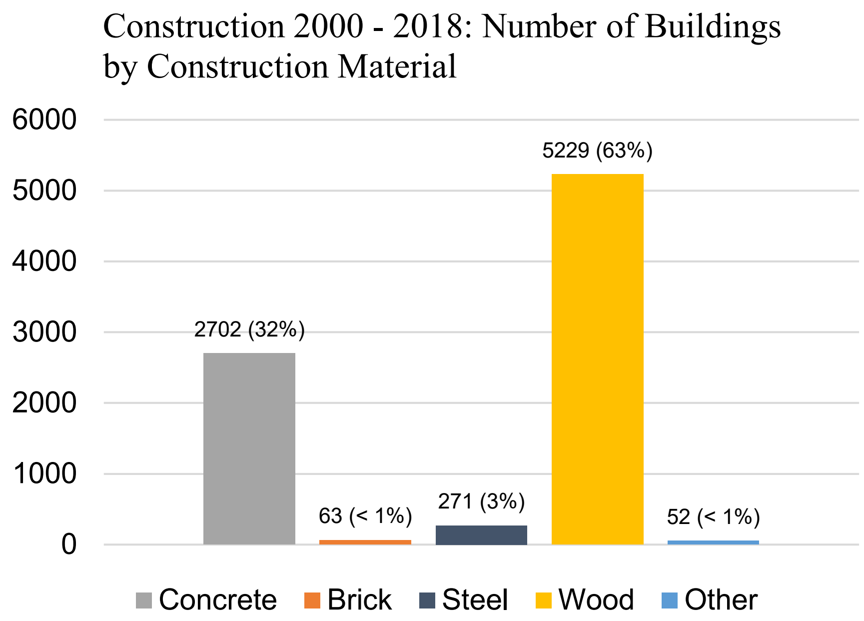
Material Composition

For newly constructed buildings, a simulation of the total numbers and floor area was made so the findings can be easier compared to demolition and stock. The data for the main construction material of buildings built between 2000 and 2018 is quite comprehensive which means that compensation was necessary for hardly any buildings.

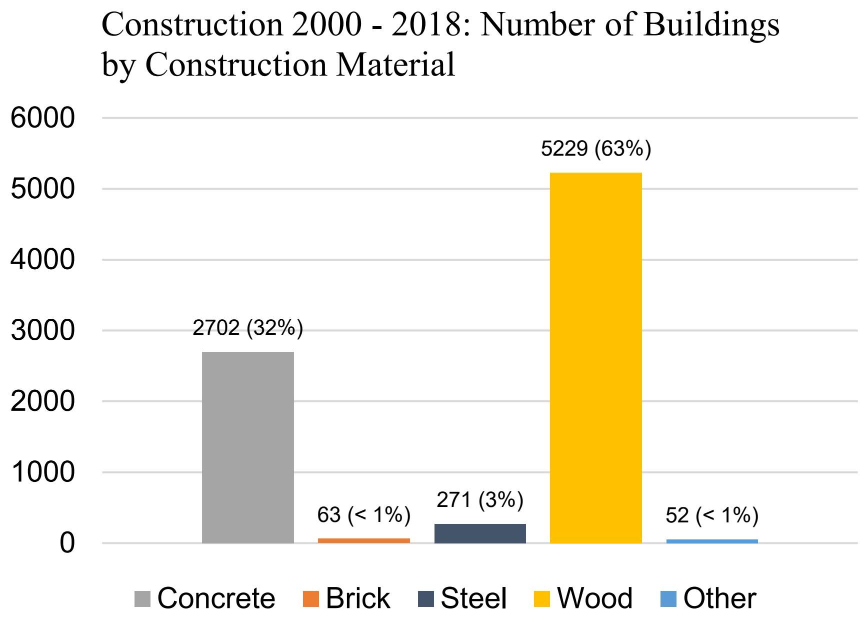
63% of all the buildings that were erected between 2000 and 2018 are made of wood (graph 4.1.3). Of these buildings, the largest share are utility buildings and detached houses which is not surprising as wood is the traditional construction material for those building types. Concrete buildings make 32% of all newly constructed buildings, the largest share make blocks of flats and detached houses. The latter comes with a bit of surprise as it is a rather untypical material for this type of building in Finland. Newly built steel buildings make 3% and brick less than 1%.

Looking at the total floor area of new construction (graph 4.1.4), more than three quarters is made of concrete. With 1 973 829 sqm, more than half of the newly built concrete floor area goes to blocks of flats (graph 4.1.6). Also, a significant size of commercial & office buildings and public buildings were built out of concrete. With 369 577 sqm, the largest amount make detached houses. Steel buildings cover approx. 5% of the newly built floor area, brick buildings are so insignificant in size that they can almost be left out of this study. The observation made for brick and concrete buildings shows that brick buildings have finally reached the bottom of popularity, replaced by concrete as a building material.

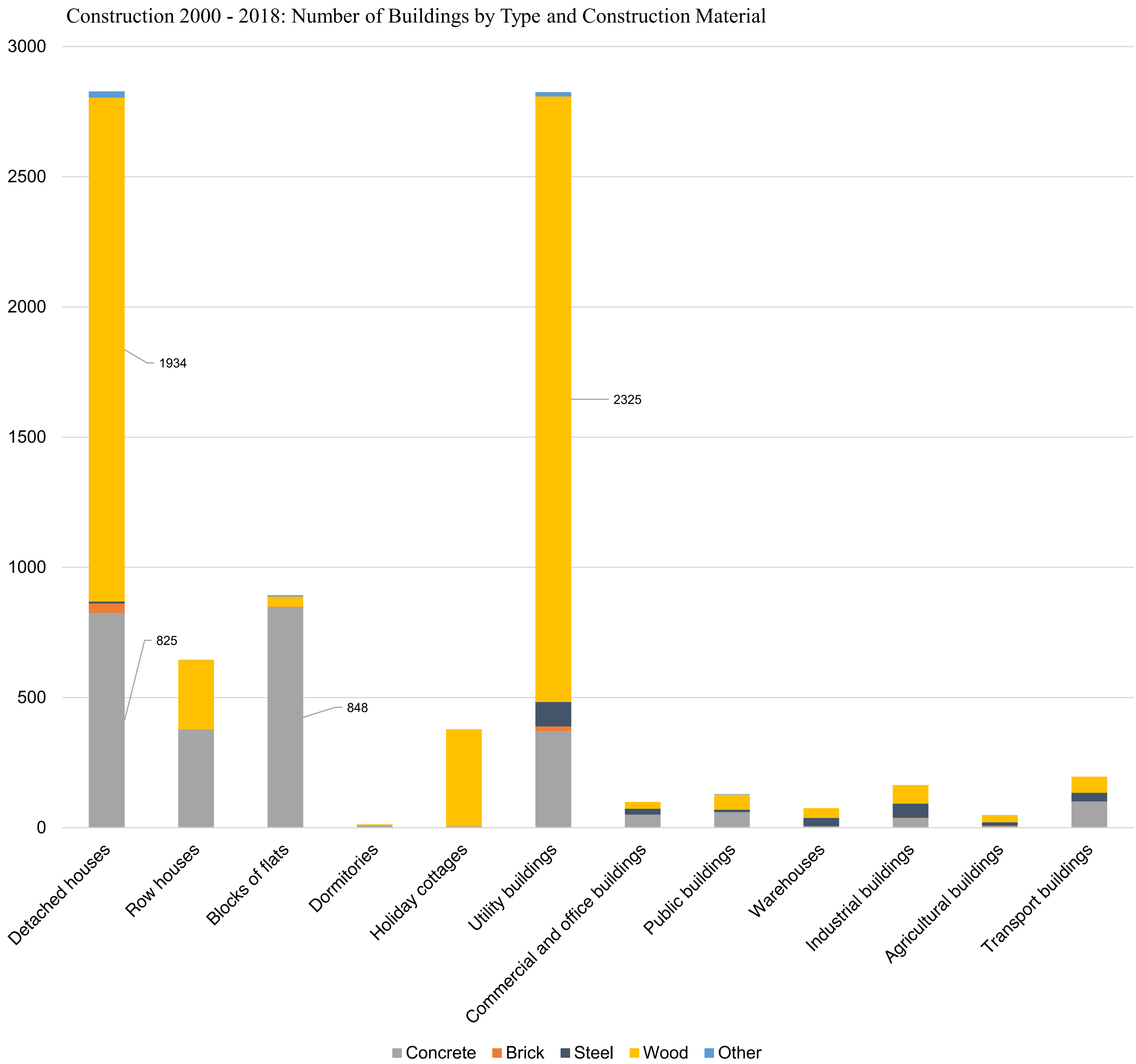
Despite its large number of new buildings, wood is mainly used for the construction of rather small building type groups such as detached houses, utility buildings and holiday cottages. The amount of concrete that was put into the building stock, especially by blocks of flats, commercial & office and public buildings is a rather alarming signal. Concrete has high values of embodied energy and emissions. Compared to wood for example, which has the potential to be, especially in Finland, a more environment-friendly material. The amount of concrete that was used for new construction already had large negative environmental impacts. Existing buildings (including new construction) need to be treated according to the circular economy in order to maintain their material value and to mitigate the amount of emissions from new construction. Especially those buildings made of carbon intensive materials like blocks of flats, commercial & office and public buildings are therefore in the focus.



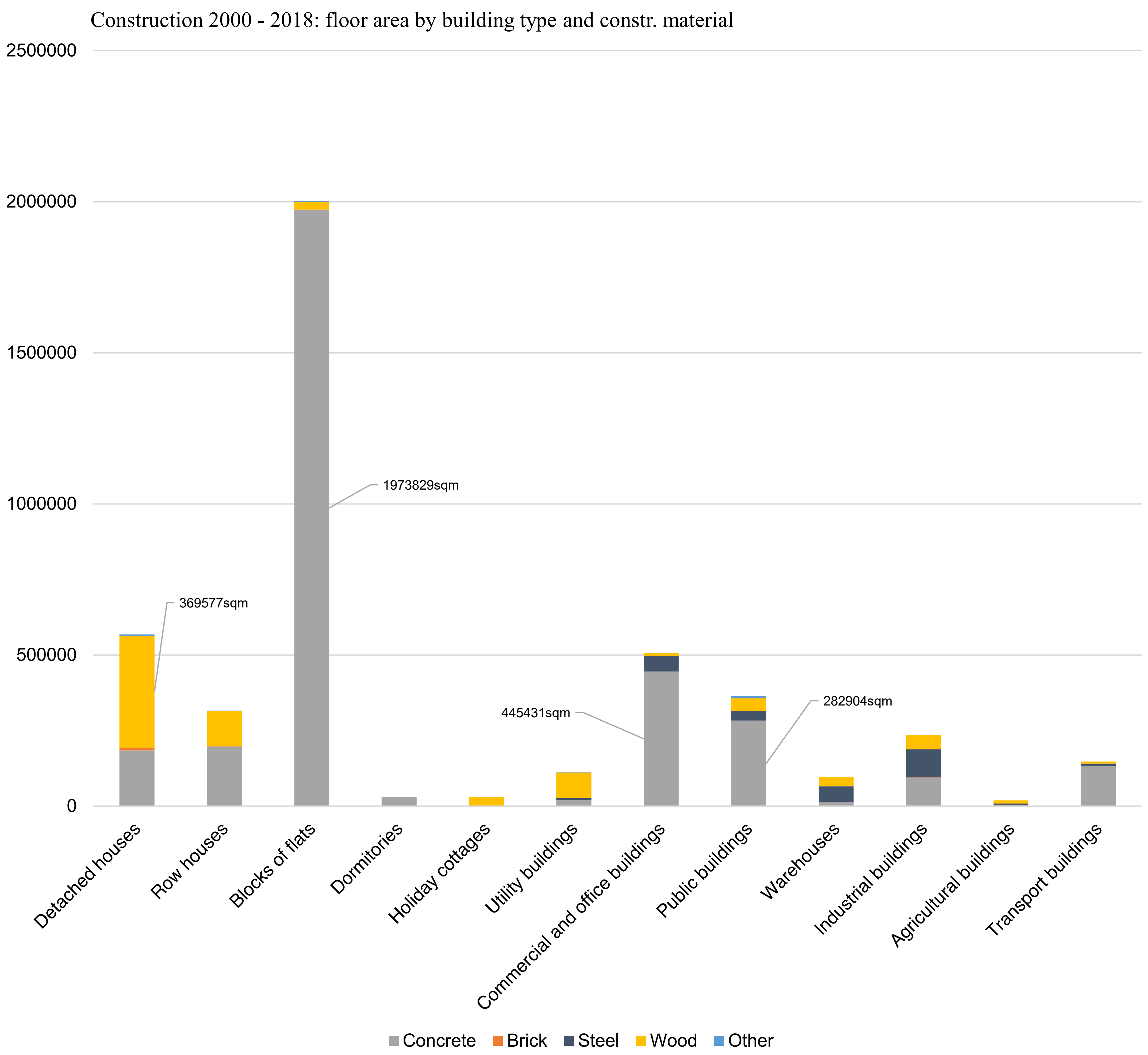
Graph 4.1.3: Material composition of new construction by number of buildings



Graph 4.1.4: Material composition of new construction by gross floor area



Graph 4.1.5: Material composition by numbers of buildings and building type



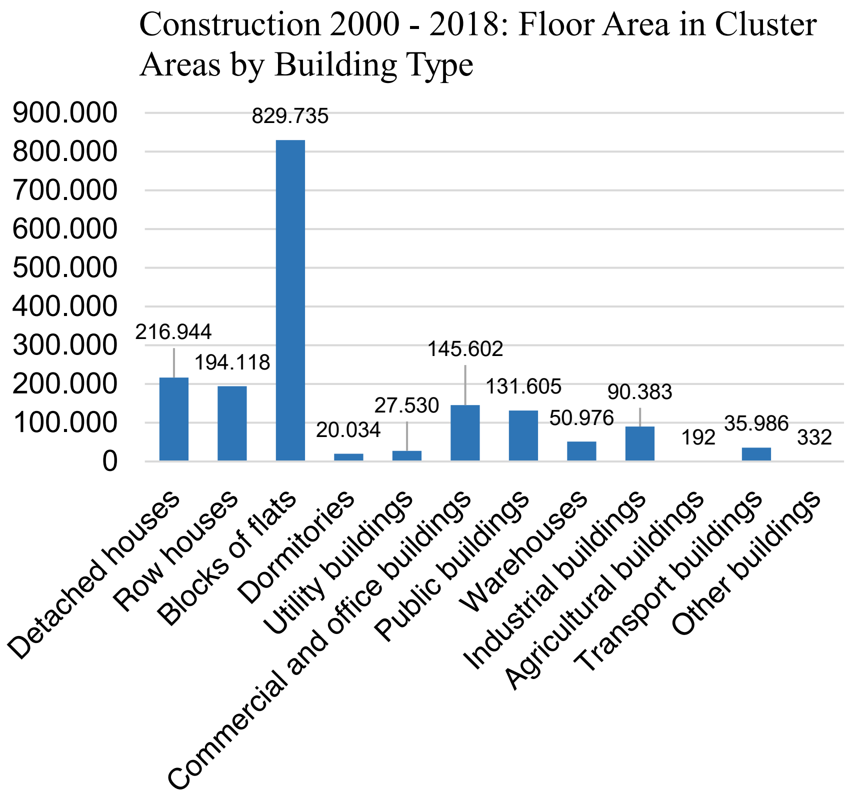
Graph 4.1.6: Material Composition by gross floor area and building type

Spatial distribution

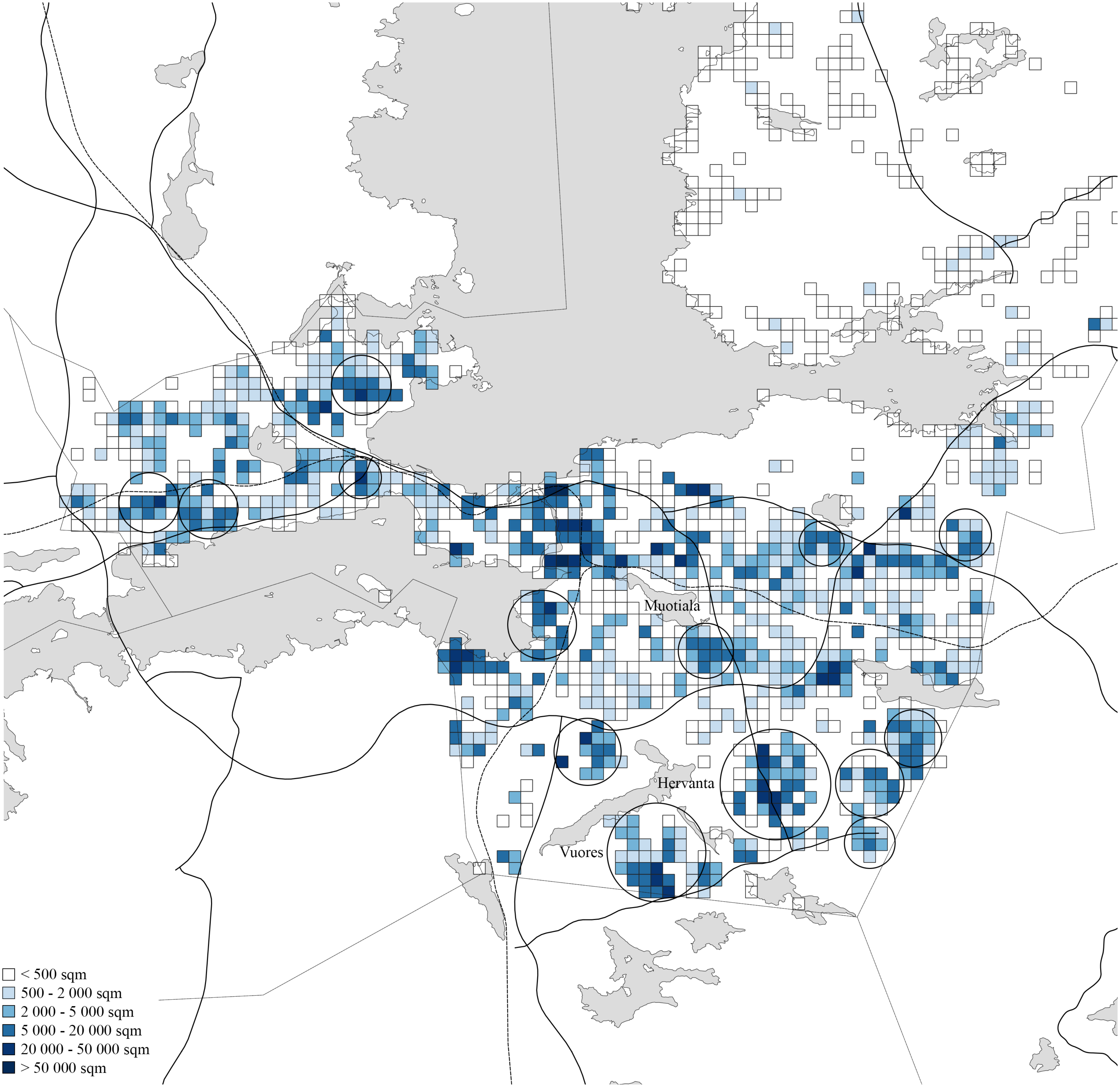
Map 4.1.7 shows the spatial distribution only for new construction between 2000 and 2018, in the Tampere city area. In some occasions, new construction formed clusters which can be categorized into different types: infill (greyfield/ brownfield) construction, greenfield development and replacement. Most of the areas, where new construction shows no direct correlation with demolition, i.e. no replacement, are greenfield developments at the edges of the city but there are also areas which can be identified as densification areas. This map shows the locations of all those cluster areas which are either infill (construction in areas where no buildings used to be) or greenfield development areas. The areas where new construction is related to demolition will be presented in the Comparison & Replacement section of the study.

The following areas Muotiala, Hervanta and Vuores are clusters of new construction which give an idea of what greenfield and infill development, in Tampere typically looked like. There chosen areas are all situated in the South-East of the city centred, Hyhky, Hervanta and Vuores. While Hyhky is greenfield development that is placed tightly in between semi-urban areas, new construction in Hervanta is densification of an already existing urban structure. Vuores on the other hand, is an expressive example of a typical greenfield development.

Clusters of new construction that stand in no direct relation with demolition – so either greenfield or infill – make in total almost 1 750 000 sqm, i.e. 40% of total new construction (see graph 4.1.8). Blocks of flats area responsible for almost half of the newly built floor area, followed by detached and row housing with each around 10% and commercially used buildings that make 8%. In other words, areas in Tampere where construction dominated were usually transformed into residential functions. While urban areas were densified with the construction of blocks of flats, greenfield areas like Vuores or Rahola had the highest percentage of loser typologies like detached or row houses. Considering the ongoing process of densification and the shrinkage of readily available greenfield areas, the construction of loose typologies can be seen critically as these building types are seldomly fit for future densification and therefore cause demolition as soon as the urban area needs to further expand. On top of that, the value of greenfield pockets in the urban fabric as biotopes and areas for recreation needs to be further acknowledged before destroying them by new construction.



Graph 4.1.8: *Total construction in cluster areas*



Tampere construction 2000 - 2018

scale | 1:85 000

Map 4.1.7: Grid of total floor area of new construction

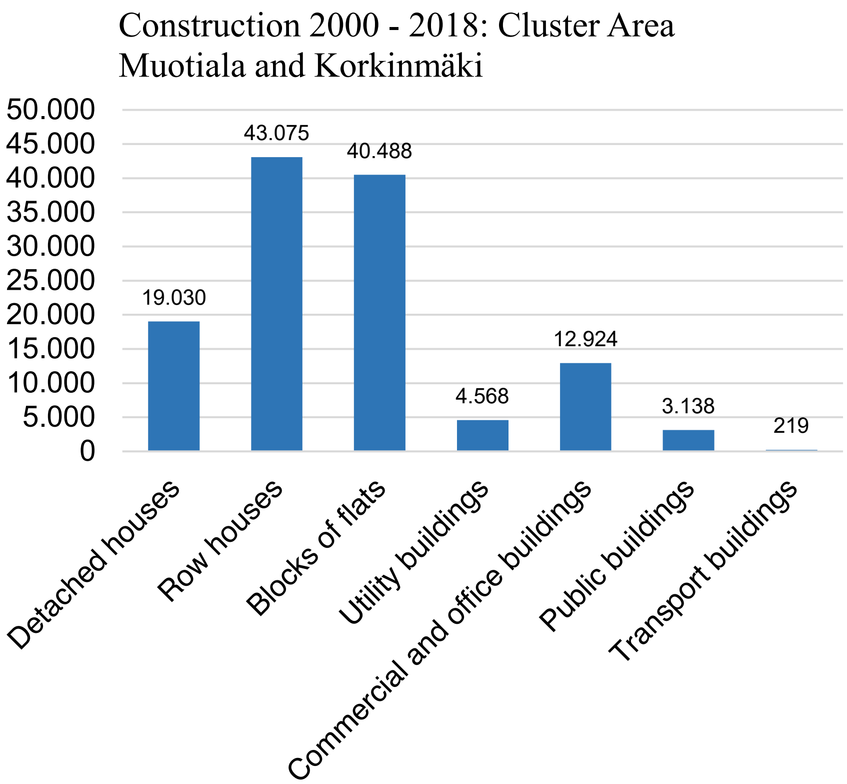
Cluster Muotiala/ Korkinmäki

The areas of Muotiala and Korkinmäki are a large neighbourhood complex that is strategically situated between Hervanta and the city centre (map 4.1.9). Even though the area covers approximately 1 square kilometre, total new construction of 123 442 sqm is relatively low. Again, more than 102 000 sqm are for residential use however, the housing typology composition explains the lower density. Only 40 000 sqm, less than half are blocks of flats. 43 000 sqm are row houses and 19 000 sqm even detached houses (graph 4.1.10).

Previous to this development, the area was mainly used as farming land, today it has its own school, kindergarten and a shopping centre on the eastern side of the Hervanta highway.

The area is a good example of how greenfields close to the urban centre of Tampere are transformed into residential areas. It can be expected that such transformation will happen more often which will result in a shrinkage of greenfields. Therefore it would be wise to think of alternatives to greenfield development. Perhaps existing urban areas could be densified.

Another examplary aspect of this area is the relatively low density of the area. In order to allow further densification, those newly developed areas must be fit for densification to avoid demolition to make way for larger, denser structures.



Graph 4.1.10: Construction in cluster area Muotiala/ Korkinmäki by building type

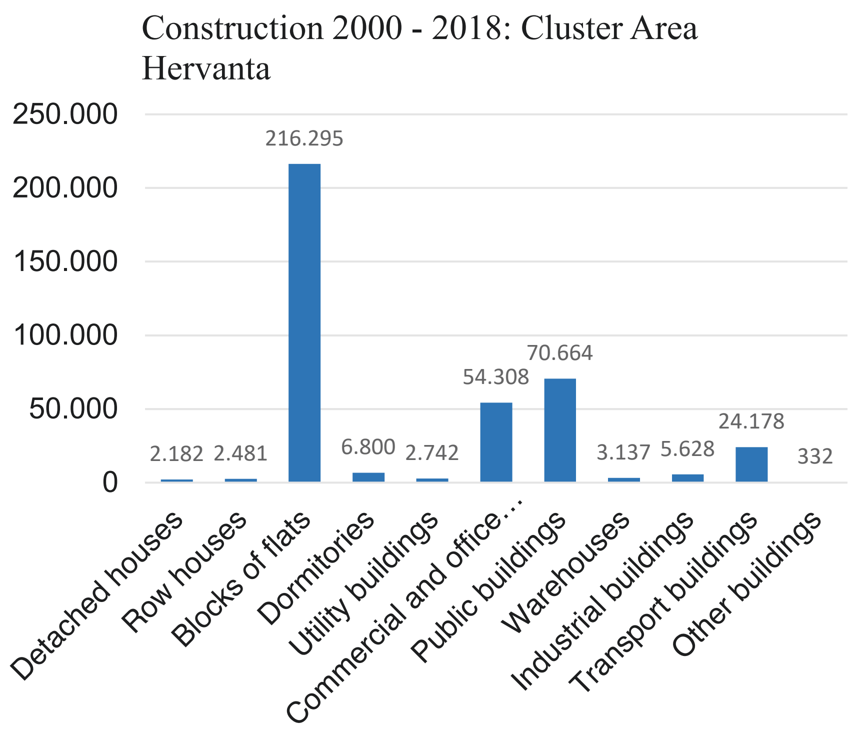
Muotiala cluster, construction 2000 - 2018 ■ existing buildings □ new construction scale | 1:5 500

Map 4.1.9: cluster area of new construction Muotiala/ Korkinmäki

Cluster Hervanta

By far, the largest cluster of mainly new construction is Hervanta (map 4.1.11). The satellite town comprises of more than 388 000 sqm of new construction between 2000 and 2018 and is therefore and outstanding example of infill development (graph 4.1.12). New construction concentrates especially along the Hervanta main road, the duo shopping center (which also marks the town center) as well as the campus area. As Hervanta's housing used to be dominated by high-rise blocks of flats it is little surprising that blocks of flats make more than 215 000 sqm of the total new construction. 70 000 sqm of newly built public buildings mainly reflects the campus area development during that time, while 54 000 sqm of commercially used buildings can be mainly found in the town center. The remaining floor area are most often transport buildings but also some low density housing or even industrially used buildings.

Hervanta is a nice example of the densifcation of an urban area. The satellite town is one of the fastest growing and most densly built areas in Tampere and the new tram line, which conntects it with the city centre, will most likely result in even further growth. The free space which was available inside the city structure was developed into housing, mainly of a higher density.



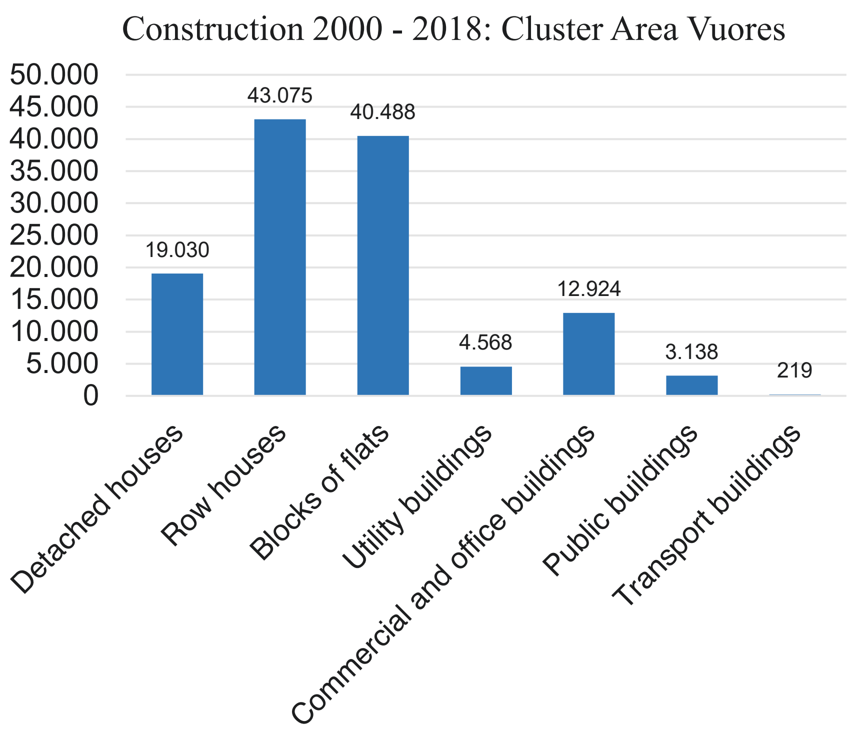
Graph 4.1.12: Construction in cluster area Hervanta by building type

Hervanta cluster, construction 2000 - 2018 existing buildings new construction scale | 1:10 000

Map 4.1.11: cluster area of new construction Hervanta

Cluster Vuores

Probably the most prominent example of greenfield development is the newly developed neighbourhood of Vuores (map 4.1.13). Situated in close proximity to Hervanta, the former forest and swamp area makes currently more than 270 000 sqm of new construction while large parts are still under construction (graph 4.1.14). Designed for more than 240 000 sqm to be used for housing, over 140 000 sqm as blocks of flats, 57 000 as detached houses and 43 000 sqm as row houses. Becoming an almost independent neighbourhood, around 22 000 sqm are used for public functions such as schools, kindergartens, sport facilities, etc. The remaining floor area especially serves housing through utility buildings.



Graph 4.1.14: Construction in cluster area Vuores by building type

Vuores cluster, construction 2000 - 2018 existing buildings new construction scale | 1:8 500

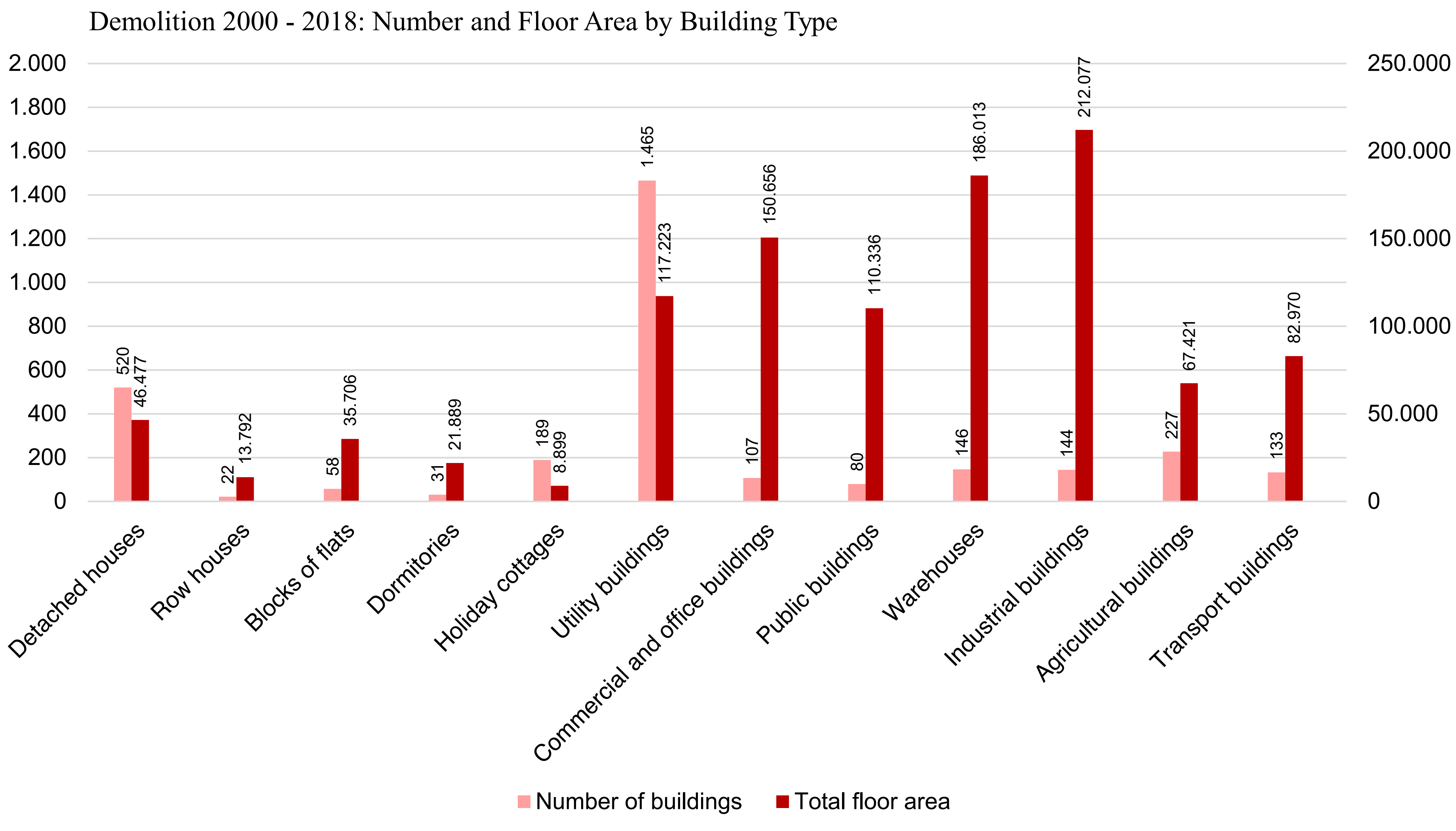
Map 4.1.13: cluster area of new construction Vuores

4.2 Demolition

Between 2000 and 2018, 3 134 buildings i.e. 1 054 061 square meters were demolished. Graph 4.2.1 shows that the majority of these buildings were utility buildings (over 45%) and detached houses which accumulate to over 15% of the total amount of demolished buildings. With only 12 demolished objects, other buildings are the least frequently demolished building type and with only 10 more, row houses make to the second last place. Looking at the share of floor area, utility buildings and detached houses together only make 15% of total demolished floor area. With 20%, industrial buildings were demolished most intensively. Warehouses make more than 17%, commercial and office buildings 14% and behind that utility buildings. As with the amount of demolished buildings, other buildings accumulate to as little as 602 sqm of demolished floor area.

It appears that especially commercially and industrially used buildings were target of heavy demolition while the floor area of demolished residential buildings can be almost neglected. The different types of ownership seem to be reflected in this finding, but it also seems that the functions of certain building types are possibly out of date, like heavy industry (and possibly warehouses) that seems to decline. The building type groups which were demolished most frequently differ from the ones that were built during the same time. It seems that there is less need of certain building types, in fact, some building type groups can be demolished without any of those buildings getting replaced by the same function.

The demolition of buildings is probably one of the most crucial aspect in this study as it shows the wasteful behaviour with the current building stock. By demolishing buildings, they do not only lose their emotional value but also the embodied energy that was put into it gets lost.

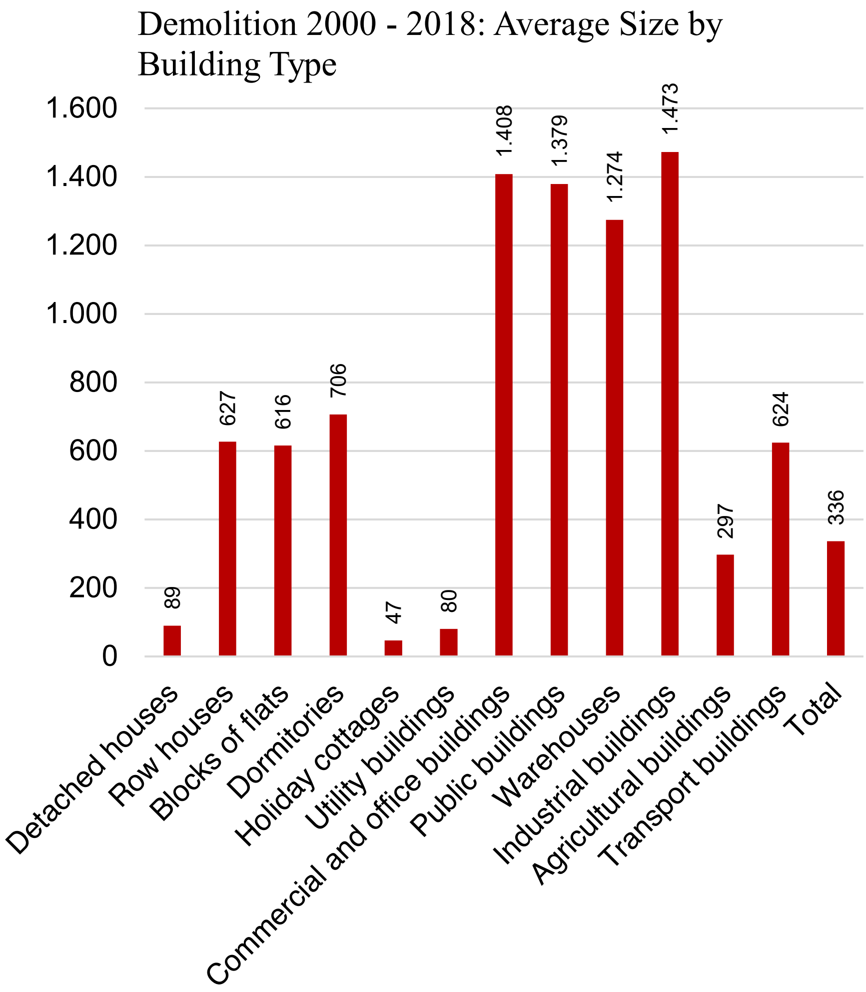


Graph 4.2.1: Demolition of buildings by total numbers, total size and building type

Average size

Graph 4.2.2 shows that the average size of demolished buildings is 336 square meters. Demolished holiday cottages are the smallest building type group in that list. Other buildings, utility buildings and detached houses come next. The largest buildings at the time of demolition are industrial buildings, commercial and office buildings are only slightly and so are public buildings and warehouses.

A preliminary comparison between demolition and new construction (chapter Comparison and Replacement goes in more detail), shows that demolished buildings were usually smaller than construction which might hint into the direction where buildings were demolished because they were too small.



Graph 4.2.2: Average Size of demolished buildings by building type

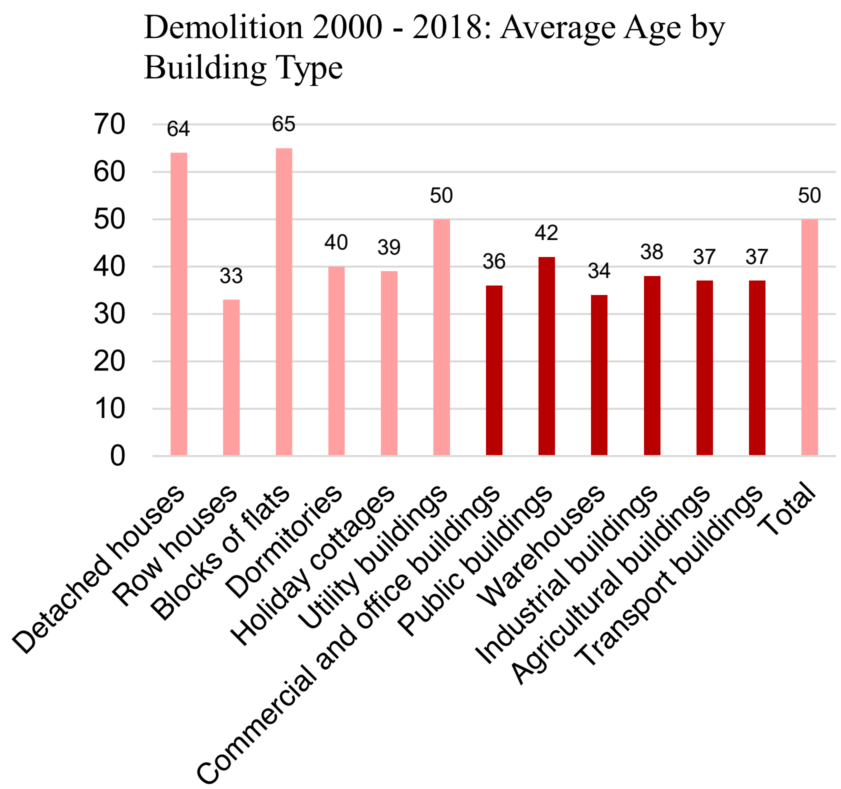
Average age

Graph 4.2.3 shows that the overall average age of demolished buildings between 2000 and 2018 in Tampere is 50 years which is in line with a study conducted by Huuhka (2016) in which Finnish buildings were found out to reach 51 years on average. The buildings that were demolished at the youngest age are row houses. As this building typology has been introduced to Finland relatively recently, this finding comes with little surprise. Also, it is one of the least frequently demolished buildings (graph 4.2.1), which makes it a finding of rather less significance. Demolished after only 34 years, warehouses are the second youngest building type, followed by commercial & office buildings which is no unusual phenomenon as commercially used buildings tend to be designed for shorter periods (Pelsmakers, 2015).

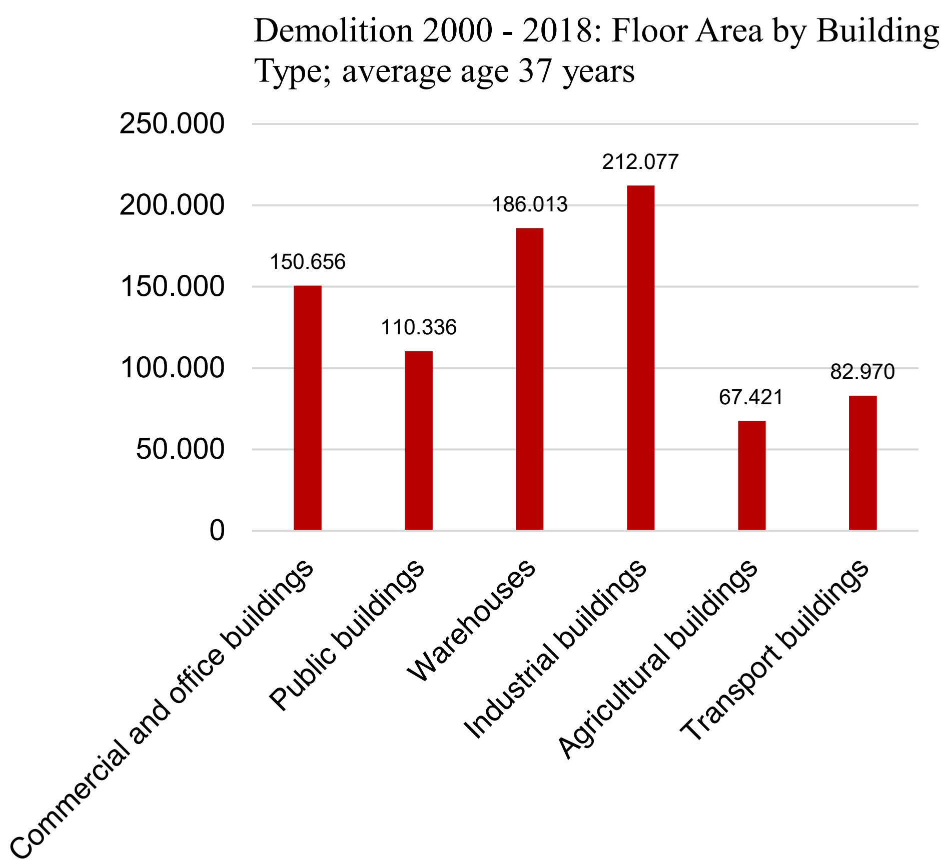
All in all, the majority of buildings has reached an age of between 35 - 40 years. With a substantial peak, blocks of flats were demolished after they have served for 65 years. Just one year less, detached houses follow a similar trend.

Large differences in the average age at the time of demolition seem to indicate that the average age of the buildings would rather correlate with their function than their construction technique. As an example, blocks of flats and commercial and office buildings are usually built in a similar way and yet there is a significant discrepancy of almost 30 years in their average ages.

It is worthwhile mentioning, that the average age is derived per building. When looking at the correlation between the average age and the actual total size, the buildings that accumulate to more than 75% of the demolished floor area (commercial & office buildings, public buildings, warehouses, industrial buildings, agricultural buildings and transport buildings) were – on average – demolished after being in use for only 37 years (see graph 4.2.4). That is more than 800 000 sqm of gross floor area in building materials going to waste or into downcycling processes after a considerably lower amount of time than on average. Considering the embodied energy of those building materials going to waste and the energy that will have to be used for the processing of the building materials that will be used in order to replace those buildings, this is a highly critical aspect to be considered.



Graph 4.2.3: Average age of demolished buildings by building type

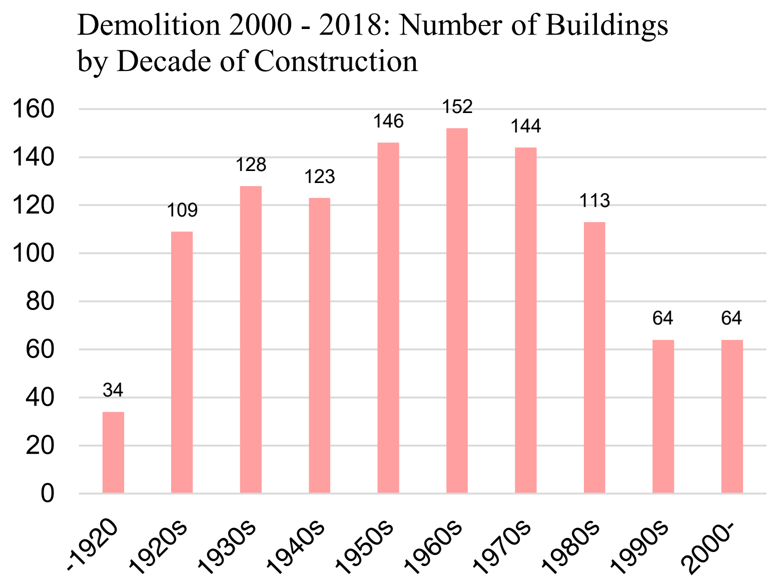


Graph 4.2.4: Demolished floor area of building types with an average age between 34 and 42

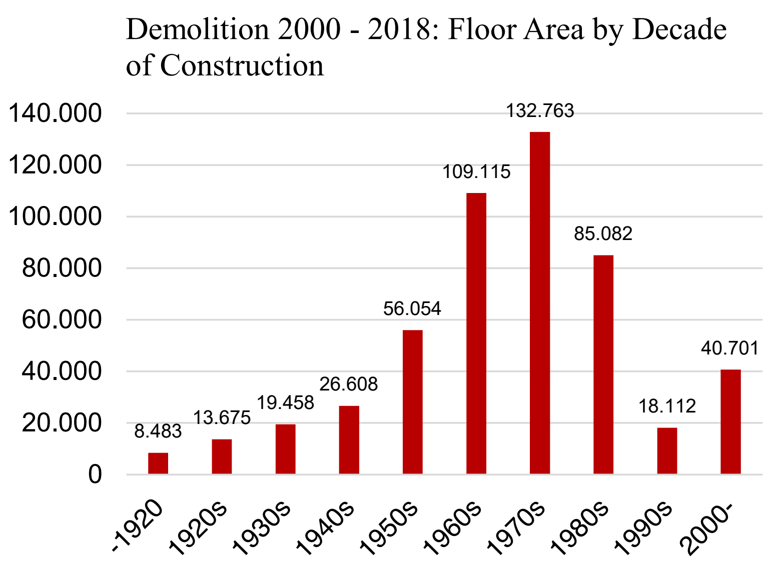
Construction Decades

For the majority of demolished buildings, the year of construction is unknown. In total, 2 057 building records have an unreliable or unknown year of construction, that makes 544 010 sqm which is more than half of the demolished floor area. For the remaining buildings, the highest points can be observed in the 1950s, 1960s and 1970s (graphs 4.2.5 and 4.2.6). This phenomenon is much more pronounced for the demolished floor area. More than 30% of the floor area that was demolished between 2000 and 2018 was built in the 1960s, 1970s and 1980s.

Due to the unreliability of the data, conclusions need to be handled with special care. Nevertheless, it seems that buildings from the 1960s and 1970s are especially threatened to get demolished.



Graph 4.2.5: Decade of construction by total numbers of buildings

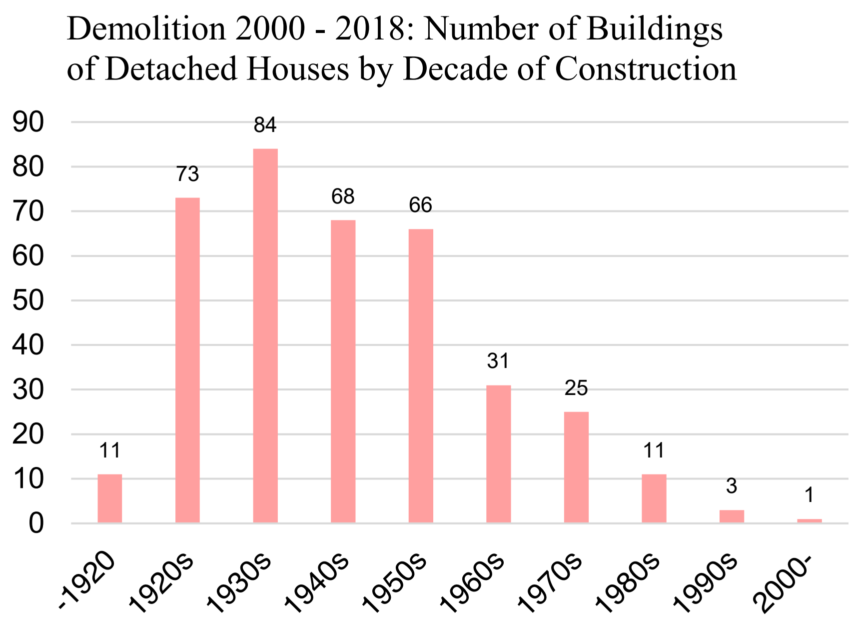


Graph 4.2.6: Decade of construction by gross floor area of buildings

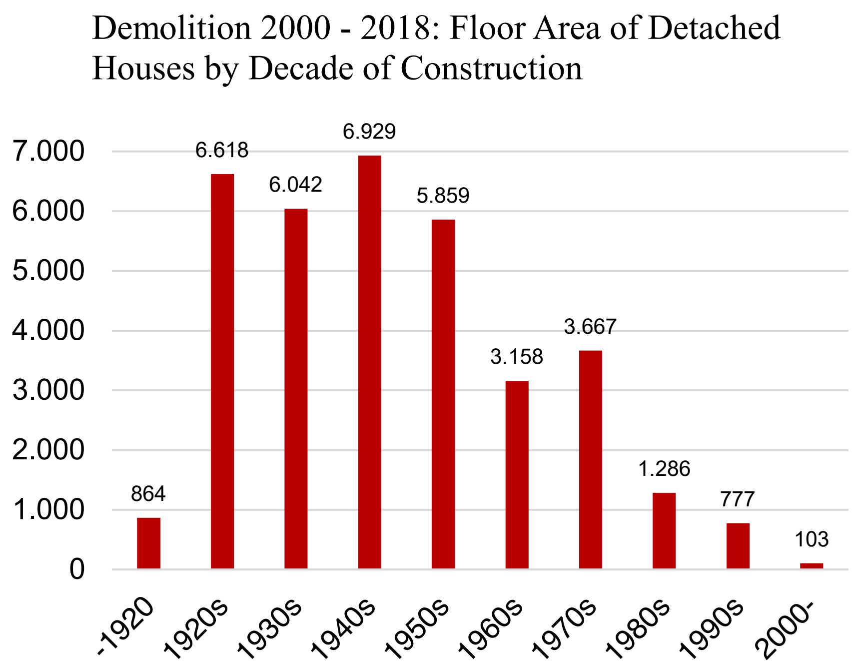
Dividing these findings by building type group and numbers of buildings, detached houses generate by far the highest peaks with up to 84 buildings annually between the 1920s and the 1950s. Most of the demolished blocks of flats were built in the 1940s, the ones that were demolished in the 1950s, however, generate by far the highest peak in floor area. The large size of demolished utility buildings in the 1940s could possibly be explained with the demolition phenomena of previously mentioned residential building type groups. The construction decades of demolished utility buildings seem to be too diverse though, to make any reliable assumptions based on any specific other building type. The 1960s mark high points especially for industrial and transport buildings. The single highest peak is formed by commercial & office buildings which were built in the 1970s. Along with warehouses, public and industrial buildings, they make over 100 000 sqm of demolished floor area from buildings of that decade.

Even though, most of the buildings that were demolished between 2000 and 2018 were built between the 1950s and 1970s, the ones that accumulated to the most amount of building floor area came from the 1960s until the 1980s. It might be worthwhile following the demolition trends of the individual building type groups and whether these evolve linearly over time. Perhaps an analysis in ten years discovers that the peaks of construction decades have also shifted ten years which might become useful for identifying those buildings which are going to become target for demolition. Any future predictions, however, need to be treated with care, as the year of construction is a very vague indicator for likeliness of demolition.

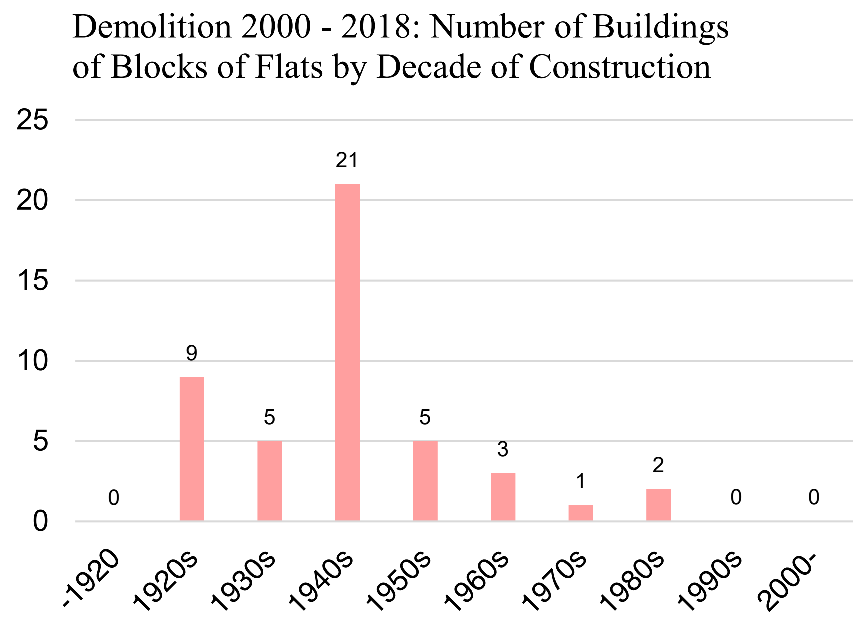
All in all, it seems that it depends highly on the individual building type, how many buildings from which decade are most likely to become demolished. It looks like it is more likely that the function and possibly building type specific properties (such as type of ownership and potentially physical attributes such as space and construction technique) have an influence on the demolition of buildings. In order to discover the main causes for demolition, it would be advisable to look at each of the building types individually.



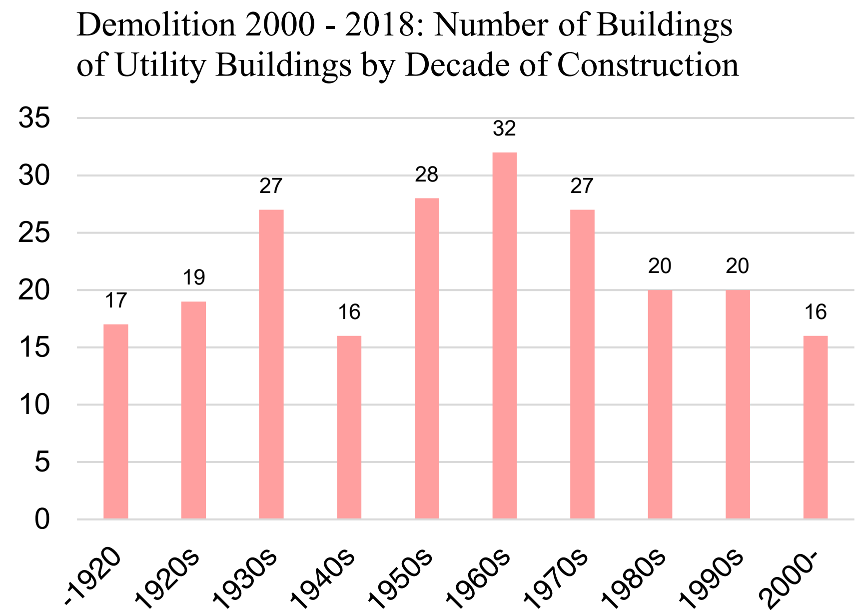
Graph 4.2.7: Decade of construction by numbers of detached houses



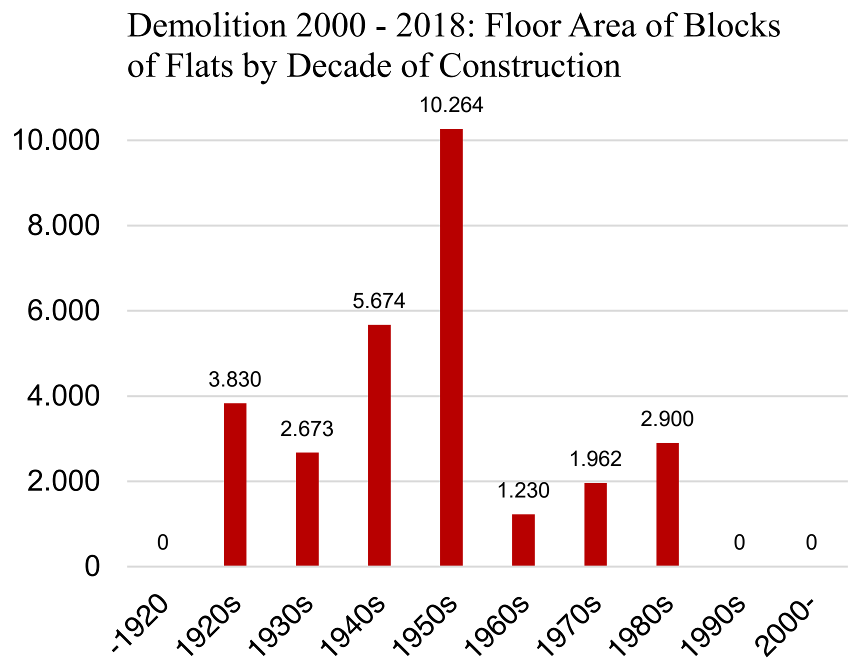
Graph 4.2.8: Decade of construction by gross floor area of detached houses



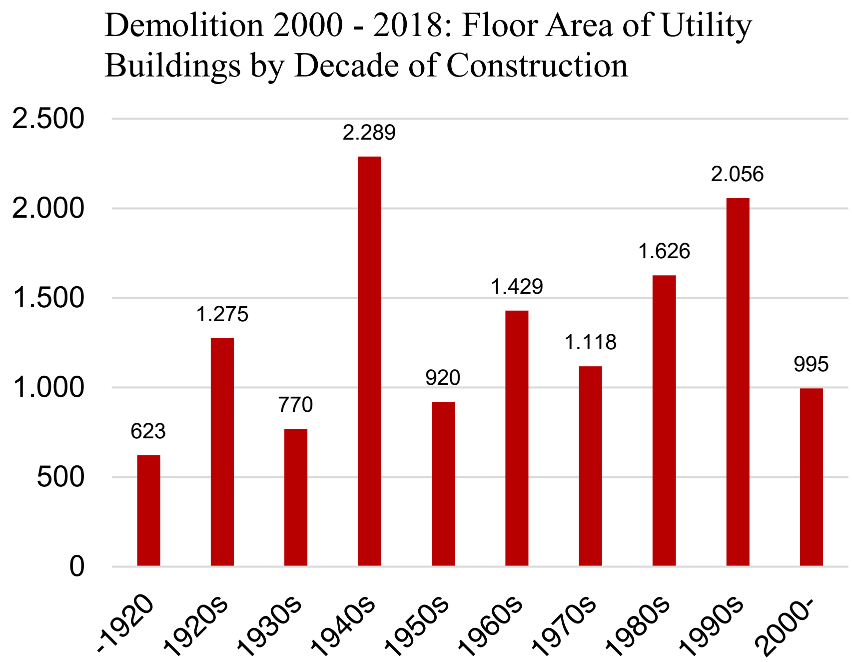
Graph 4.2.9: Decade of construction by numbers of blocks of flats



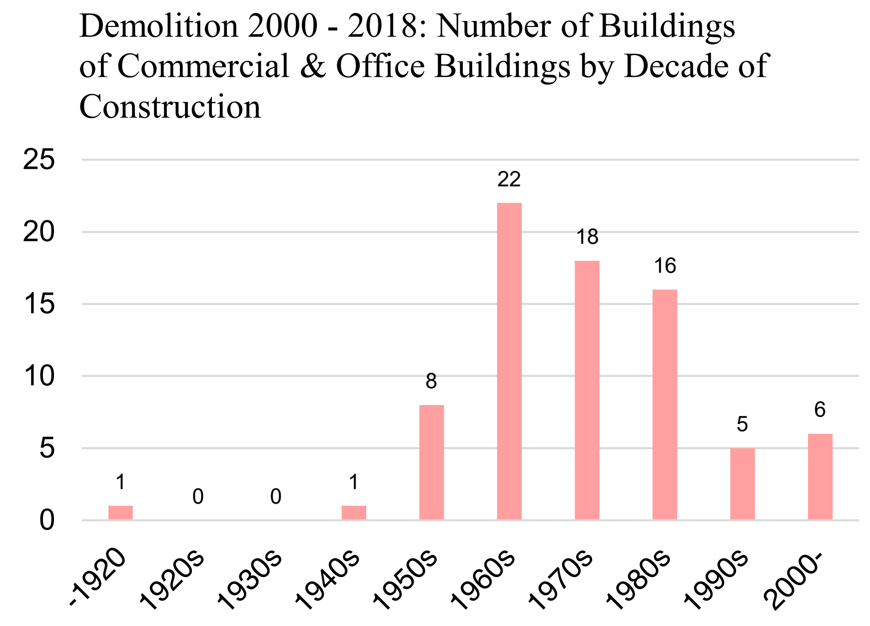
Graph 4.2.11: Decade of construction by numbers of utility buildings



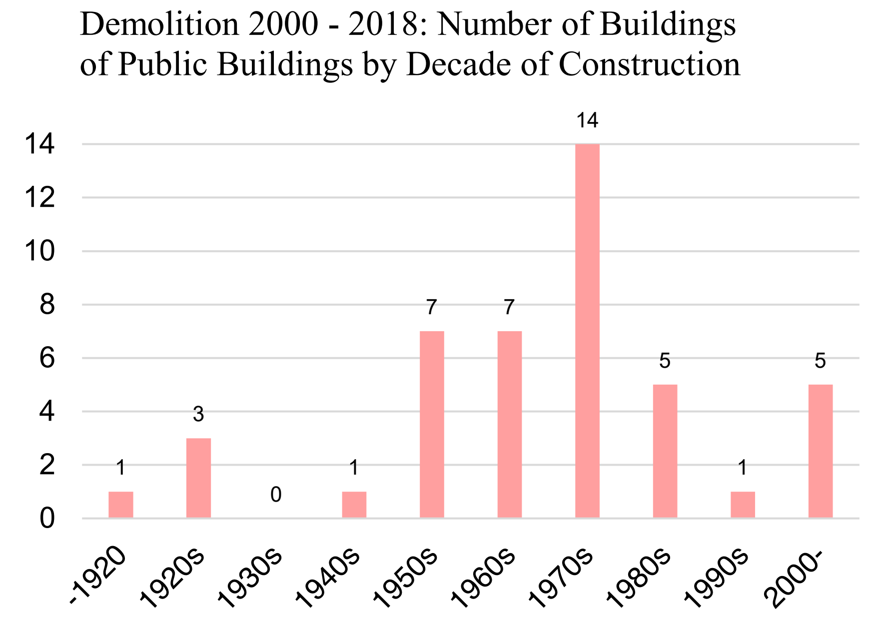
Graph 4.2.10: Decade of construction by gross floor area of blocks of flats



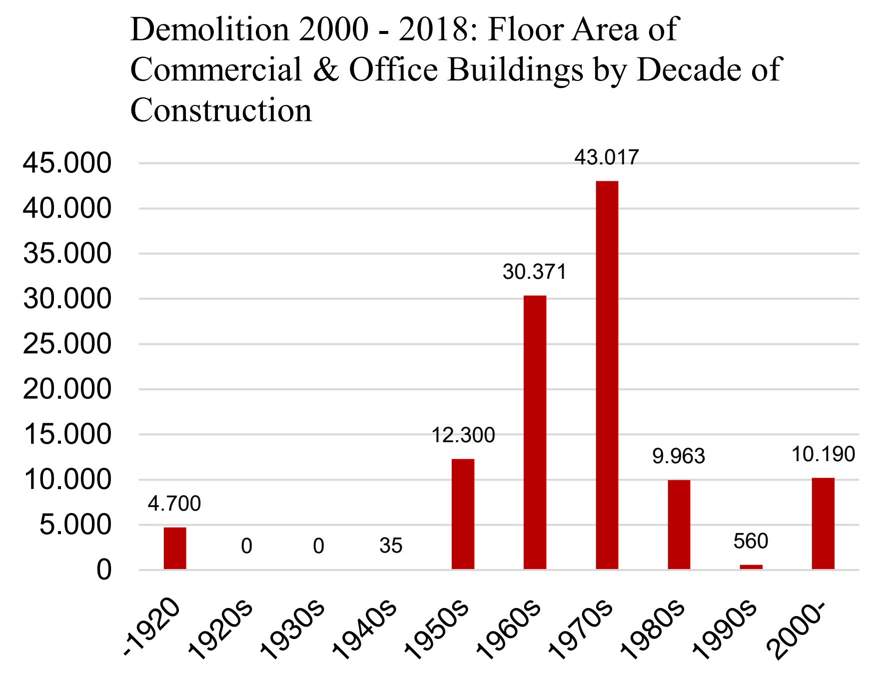
Graph 4.2.12: Decade of construction by gross floor area of utility buildings



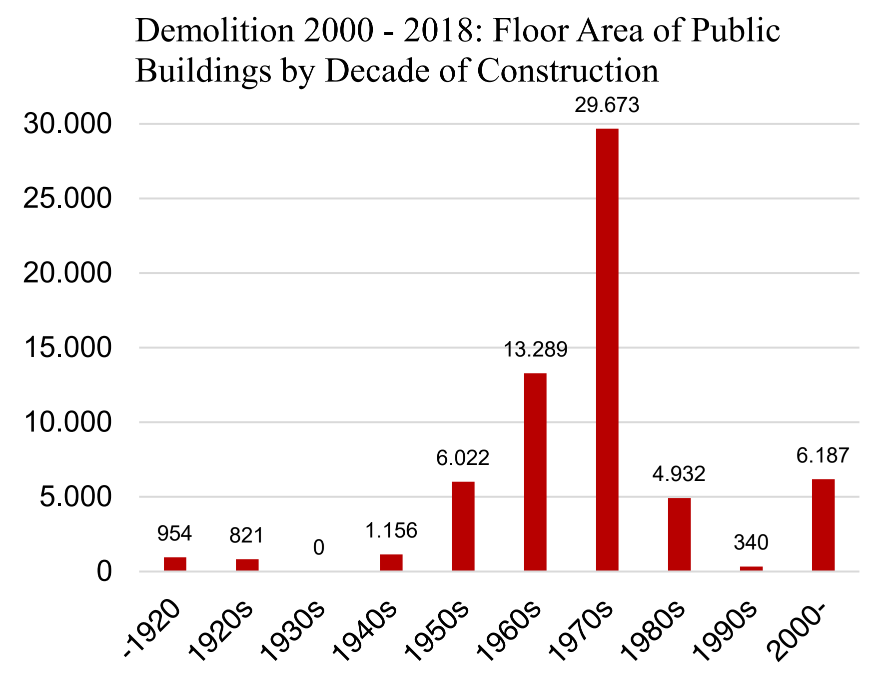
Graph 4.2.13: Decade of construction by numbers of commercial & office buildings



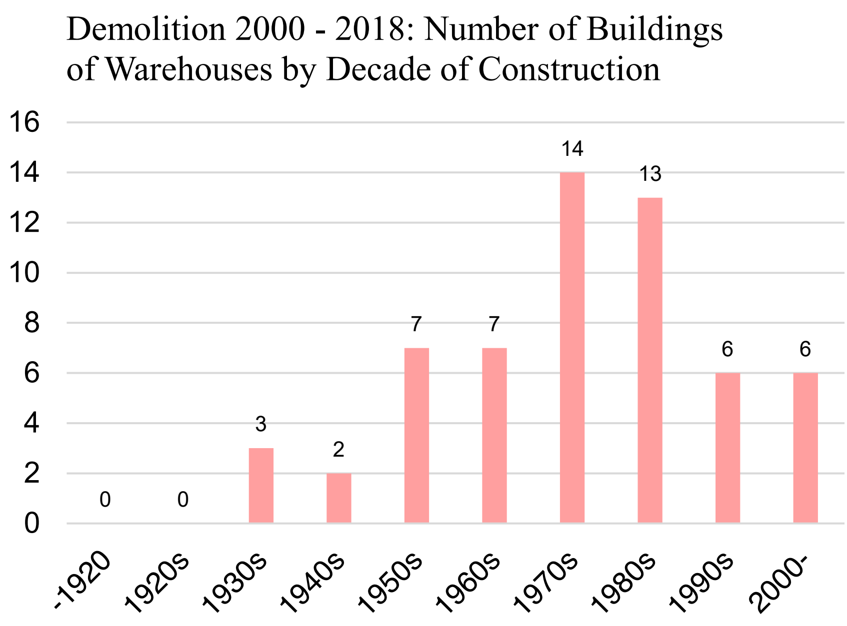
Graph 4.2.15: Decade of construction by numbers of public buildings



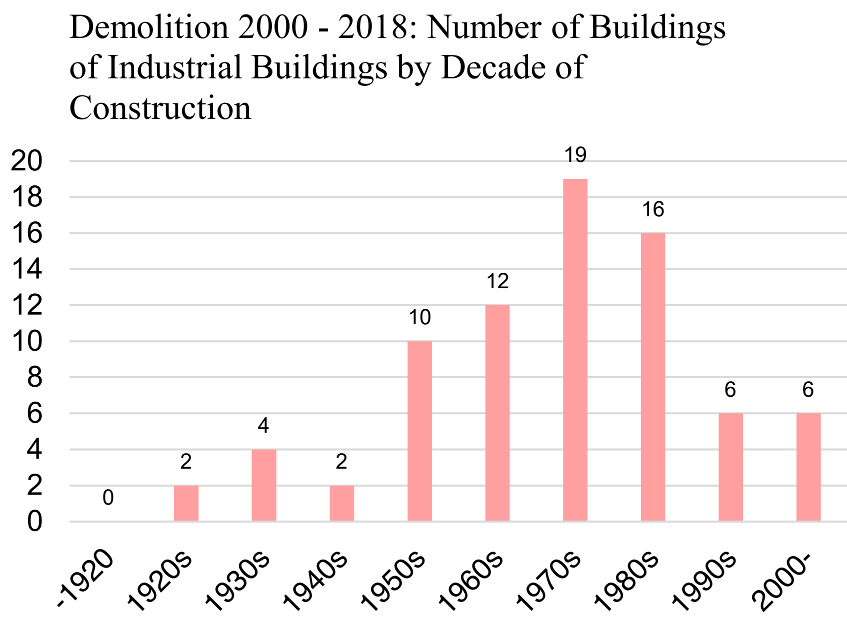
Graph 4.2.14: Decade of construction by gross floor area of commercial & office buildings



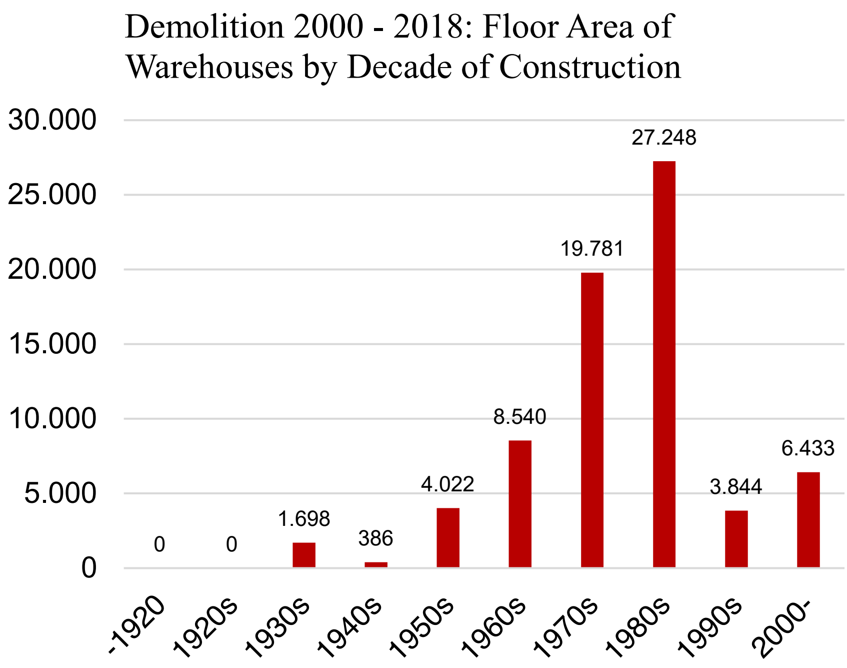
Graph 4.2.16: Decade of construction by gross floor area of public buildings



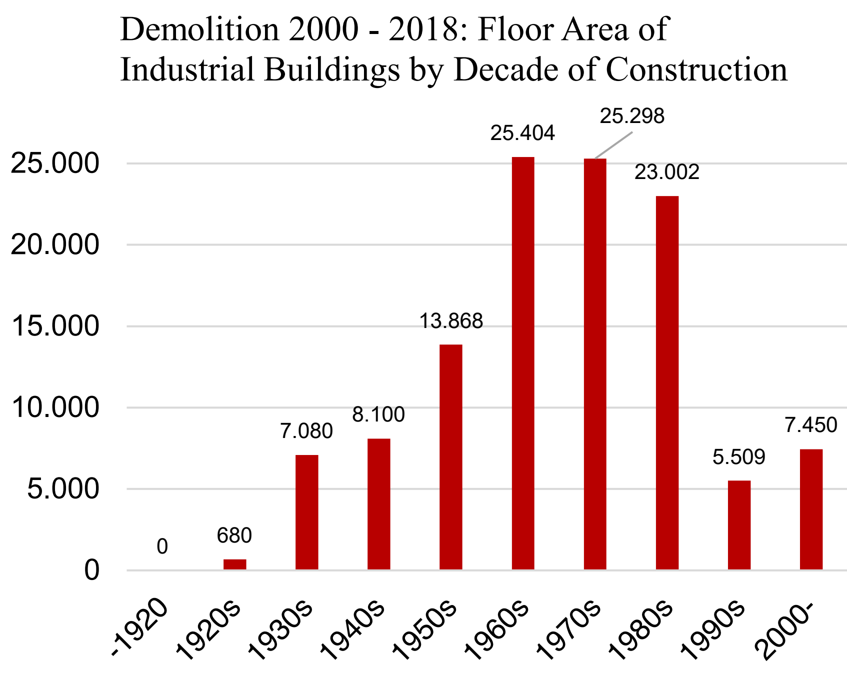
Graph 4.2.17: Decade of construction by numbers of warehouses



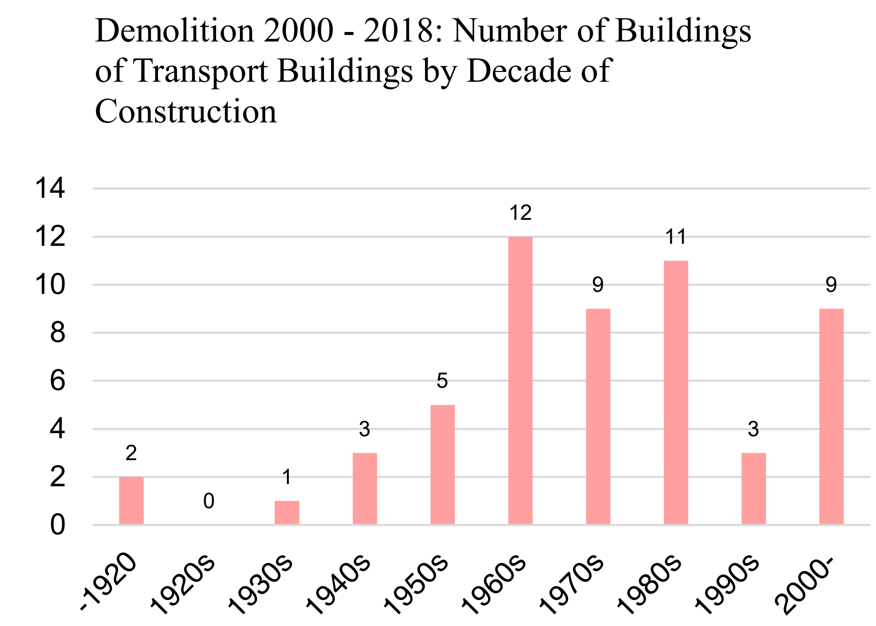
Graph 4.2.19: Decade of construction by numbers of industrial buildings



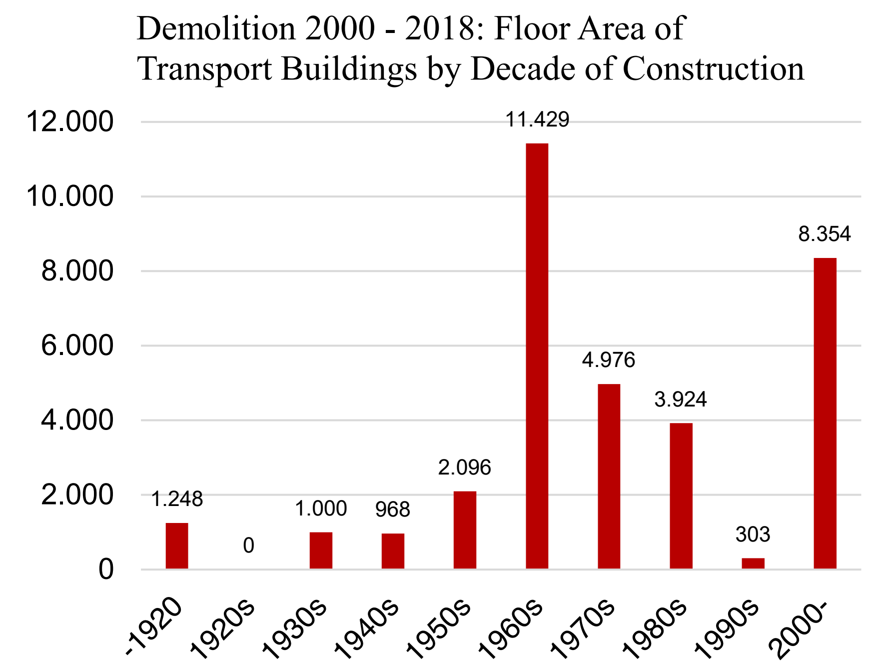
Graph 4.2.18: Decade of construction by gross floor area of warehouses



Graph 4.2.20: Decade of construction by gross floor area of industrial buildings



Graph 4.2.21: Decade of construction by numbers of transport buildings



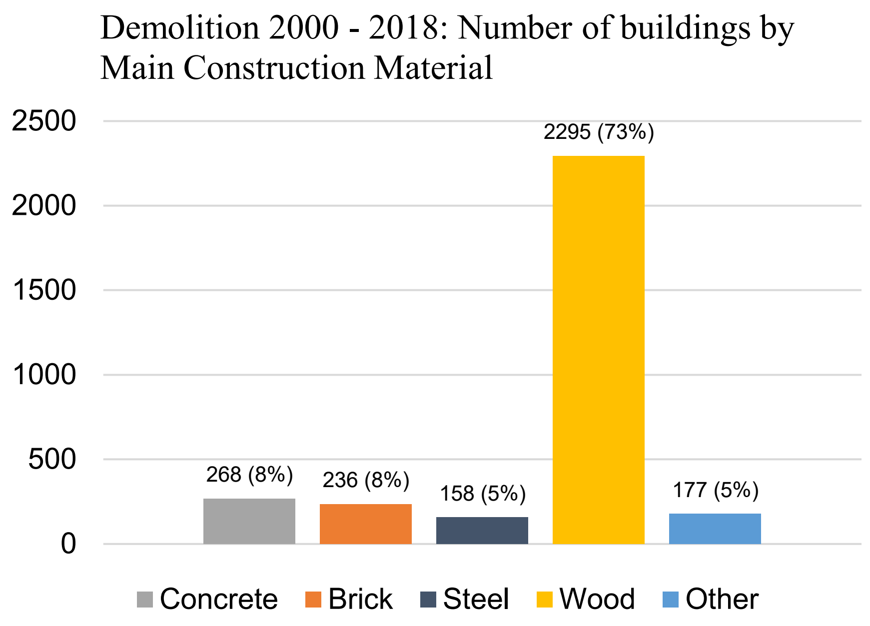
Graph 4.2.22: Decade of construction by gross floor area of transport buildings

Material Composition

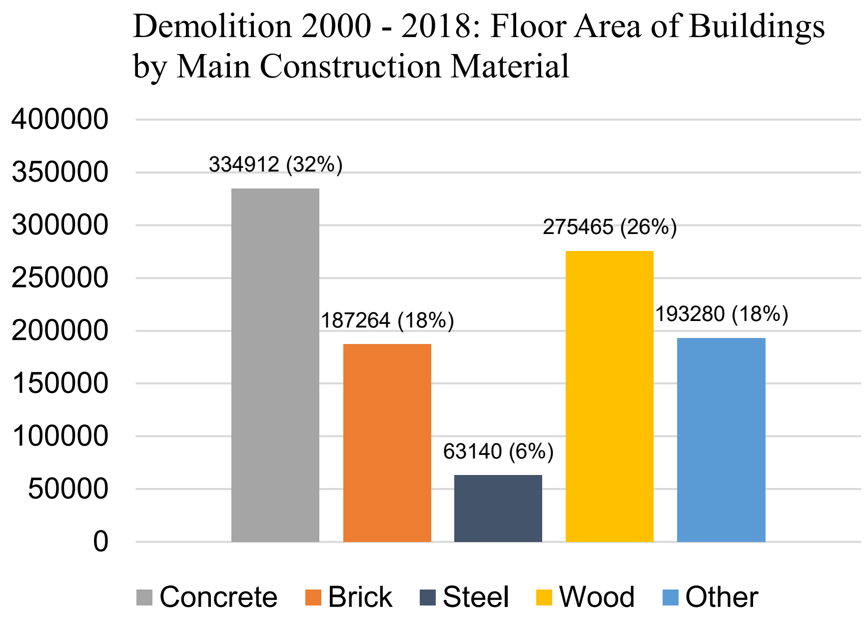
In total 2 140 out of 3 134 buildings lacked information about the construction material. Only some 32% of the buildings and 48% of the built floor area contained information regarding the main construction material. Therefore, the simulated total numbers made for demolished buildings need to be treated with special care.

Graph 4.2.23 shows that 73% of the demolished buildings are made of wood which comes with little surprise, considering the material composition of the most frequently demolished building type groups like utility buildings and detached houses (graph 4.2.25). Concrete on the other hand, accumulates to 32% of demolished floor area (graph 4.2.24) which is the biggest single share. Most of demolished concrete floor area comes from warehouses, commercial & office, public and industrial buildings (graph 4.2.26). Generally, the material composition of demolished buildings seems much more heterogenic than construction. There is not a single construction material that stands out which might indicate that it might be less when searching for the reasons of demolition.

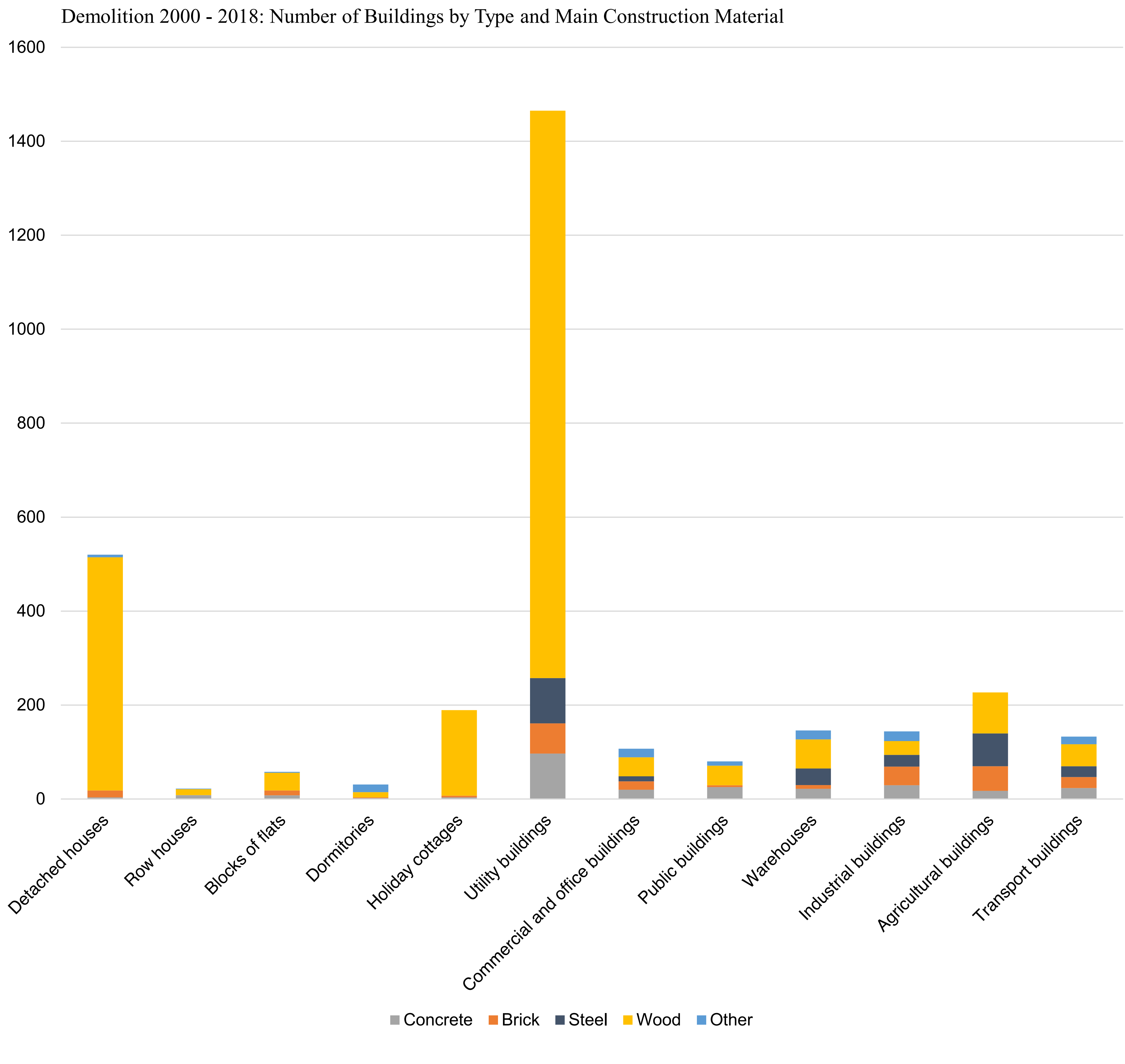
Nevertheless, more than half of the total demolished floor area was made of carbon intensive construction materials such as concrete, brick and steel. For future demolition, these construction materials need to be treated with more care to allow them to go back into new construction in order to reduce the embodied emissions caused by the material manufacturing.



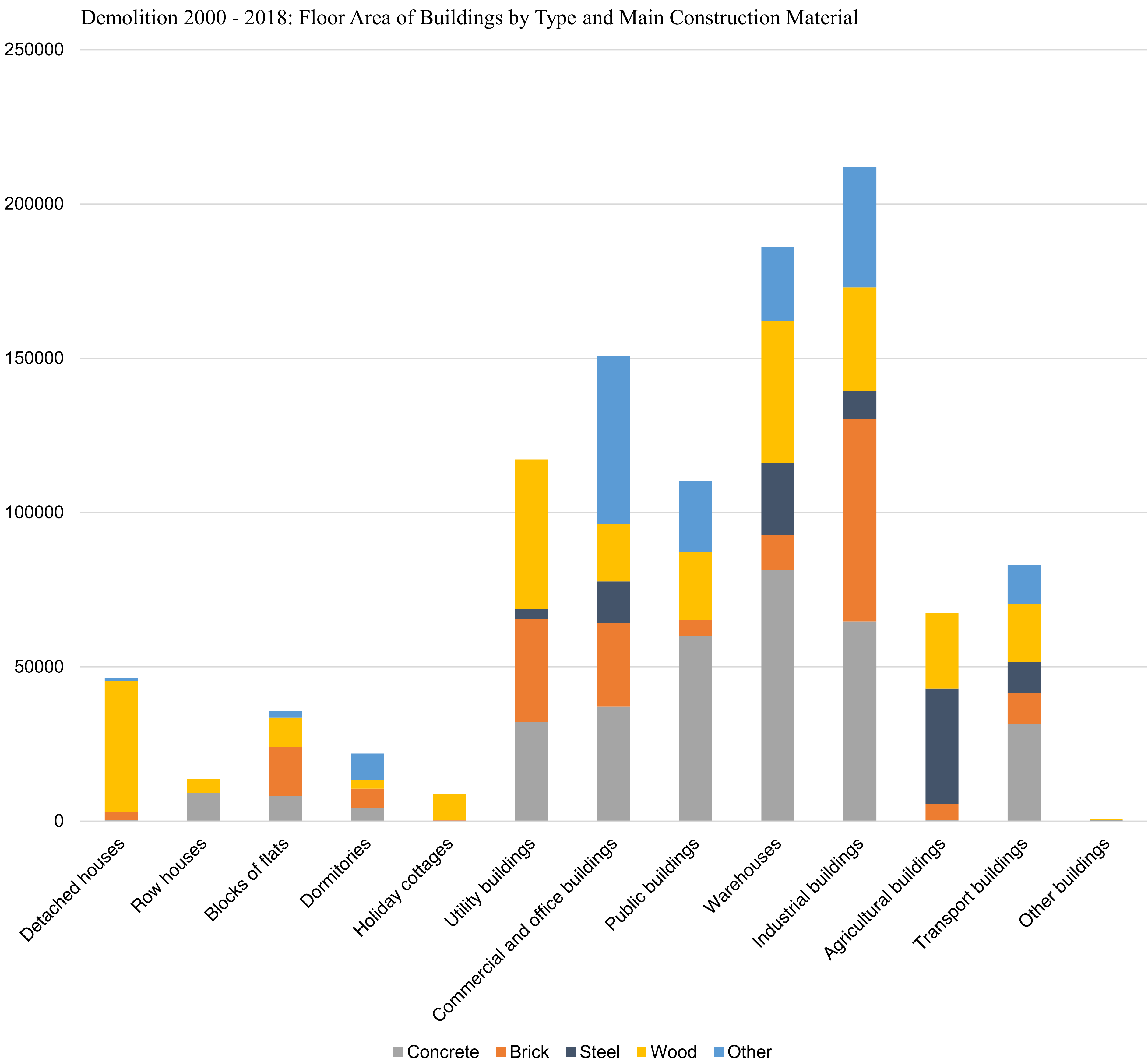
Graph 4.2.23: Material composition by total numbers of buildings



Graph 4.2.24: Material composition by total gross floor area of buildings



Graph 4.2.25: Material composition by numbers and building types



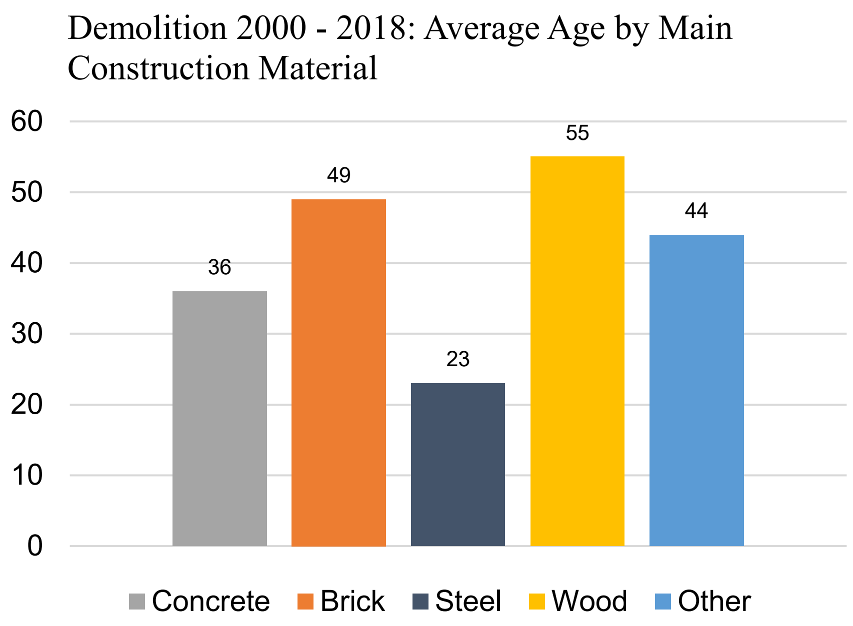
Graph 4.2.26: Material composition by gross floor area and building types

Graph 4.2.27 shows that with an average age of 55 years at the time of demolition, wooden buildings existed for the longest time in Tampere. Considering the possibility of wood being a very sustainable construction material, its ability to withstand for over half a century adds to its environmental value.

The fact that demolished brick buildings in Tampere are among the oldest reflects the city's industrial background and its many older brick buildings. Graph 4.2.6 proofs that the largest share of demolished floor area of brick buildings has been industrially used.

Concrete buildings were demolished after an average age of 36 years. Steel buildings, as an even more carbon intensive construction material, have been demolished after only 23 years. The fact that buildings of these high-emission construction materials have reached, by far, the shortest age, must be considered as an issue. Especially those buildings and their materials need to be protected from wasteful demolition in order to reduce emissions. Nevertheless, concrete and steel are relatively young construction materials in the Finnish building stock. While brick and wood are the more traditional materials, concrete and especially steel became most popular between the 1950s and 1970s which partly explains their young average age.

Overall, these numbers must not be treated as future predictions. Also, the average age of construction materials does not necessarily reflect their robustness. It is more likely that other factors have bigger impacts on the lifespan of a building than the construction material.

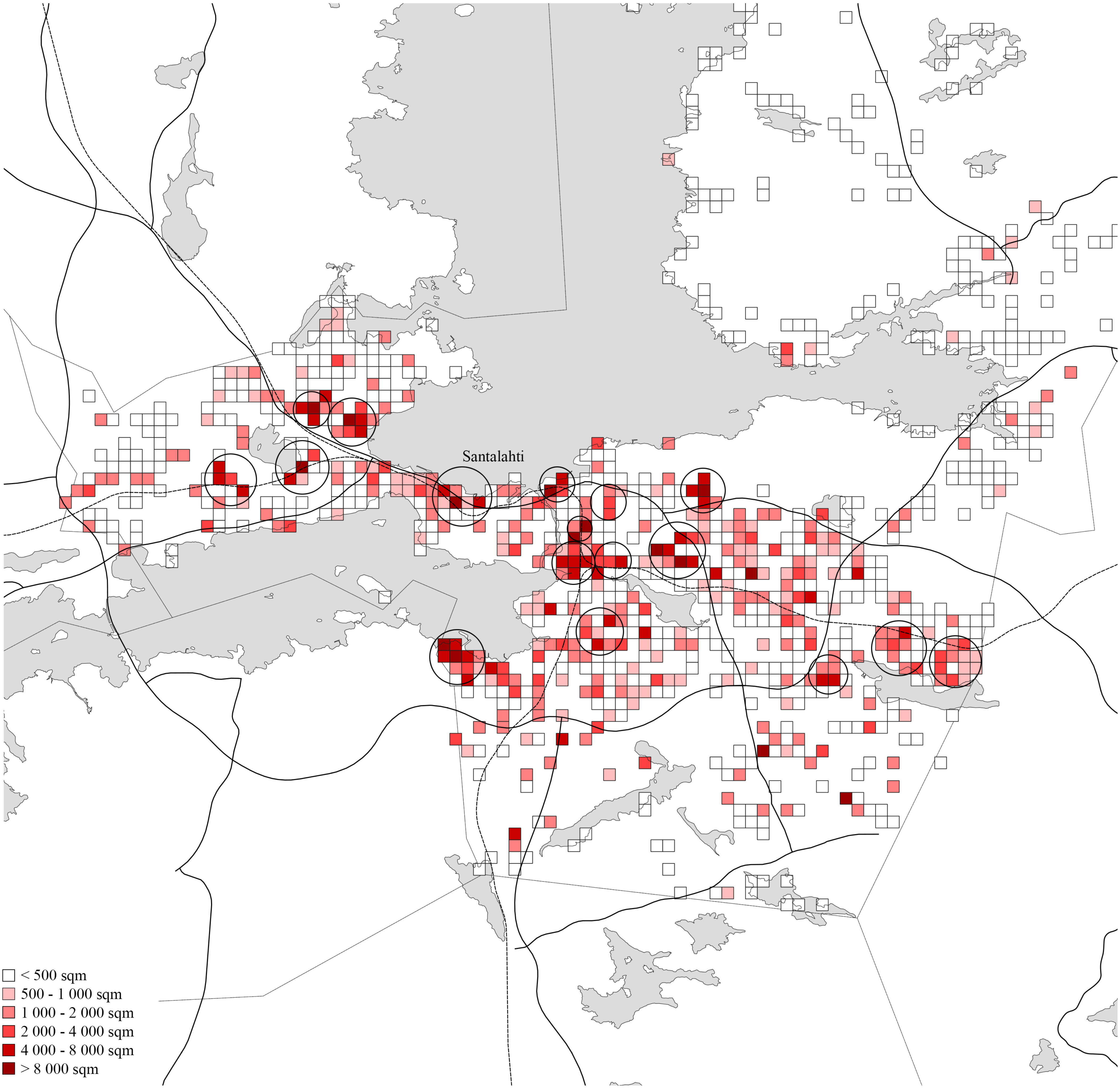


Graph 4.2.27: Average age by construction material

Spatial Distribution

The following map 4.2.28 shows the distribution of buildings demolished between 2000 and 2018 in the city of Tampere. Most of the clusters that can be identified here are replacement areas. In total, there are only few clusters in which demolition dominates and new construction hasn't followed after. These are mostly brownfields and greyfields of which some are waiting to be turned into residential and mixed residential-commercial districts in near future. In other cases, demolition was stirred by traffic developments however, in most of the areas, the phenomenon is too diverse to identify any obvious pattern. In total, almost half of all demolition occurred in clusters.

Nevertheless, it can be said that demolition does not happen without a reason. It is expansive and often the result of some kind of development, either new construction of buildings or traffic development.



Tampere demolition 2000 - 2018

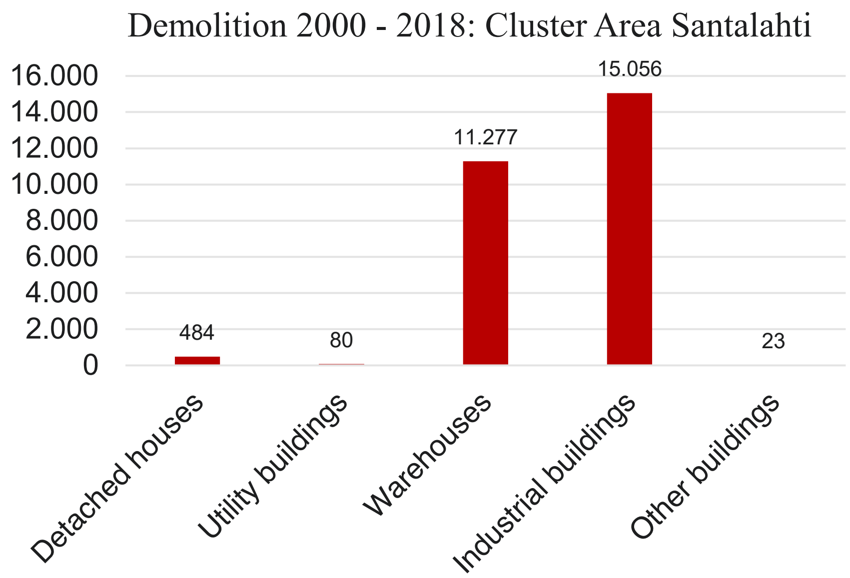
scale | 1:85 000

Map 4.2.28: Grid of total floor area of demolition

Cluster Santalahti

Santalahti is situated on the southern shore of Näsijärvi just one kilometre west of Tampere and this area forms a cluster for demolition (map 4.2.29). In total 26 920 sqm of gross floor area were demolished which were almost entirely old warehouses and industrial premises (graph 4.2.30). The map shows that the area is in the middle of a transformation process. In the eastern part of the cluster, demolished buildings have already been replaced by new construction, mainly residential buildings. The other demolished buildings in the area are going to be replaced based on the new town plan asemakaava 8048. The area, which comprised of mainly industrially used buildings warehouses, is going to be developed into a new residential area.

The new masterplan in the area covers the demolished buildings so technically, the area is a replacement area where new construction just has not yet happened. Nevertheless, Santalahti showcases typical demolition patterns which are usually caused by the development of traffic or construction of buildings.



Graph 4.2.30: Demolition in cluster area Santalahti by building type

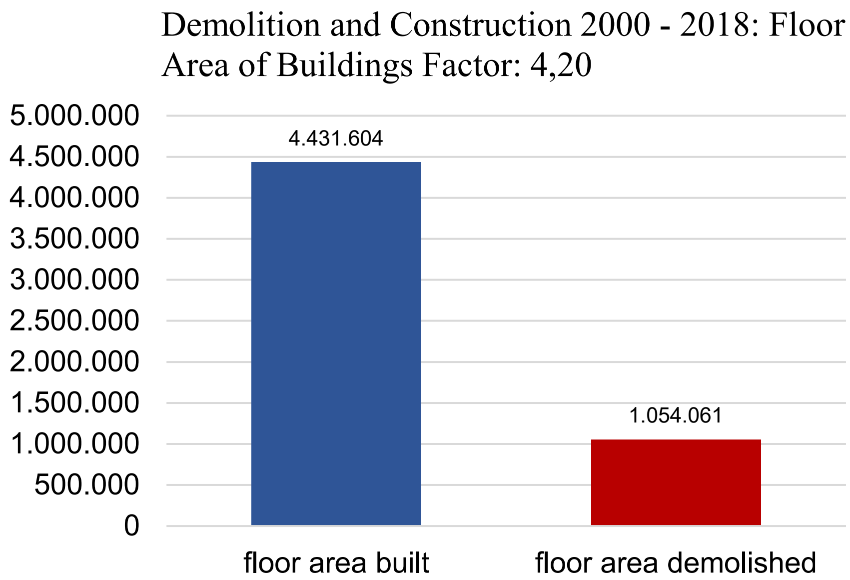
Santalahti cluster, demolition 2000 - 2018 ■ existing buildings □ new construction □ demolition scale | 1:5 000

Map 4.2.29: cluster area of demolition Santalahti

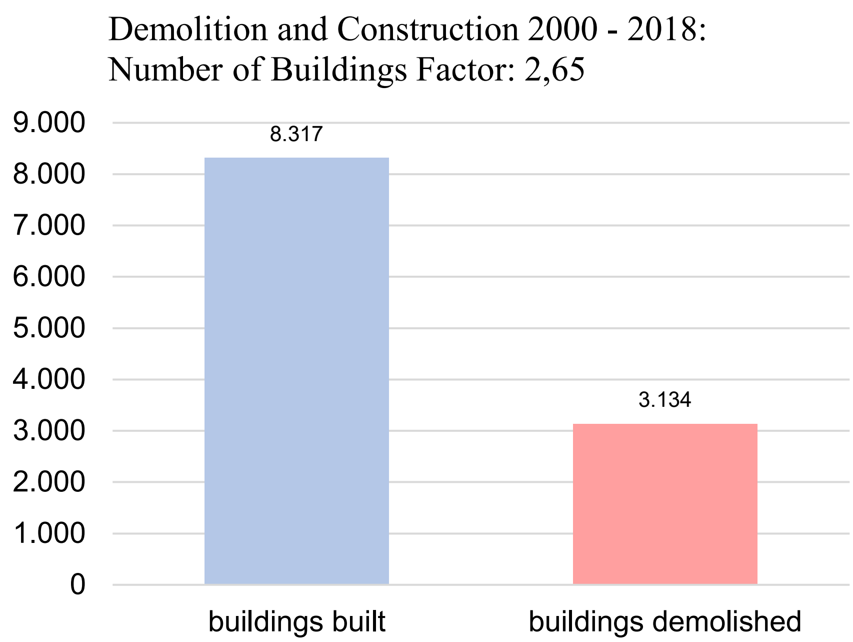
4.3 Comparison & Replacement

Graph 4.3.1 shows that the amount of new buildings exceeds demolished buildings by the factor 2,65, while the floor area of new construction exceeds demolition even by 4,20 (graph 4.3.2). Looking at the average size of demolition and new construction (graph 4.3.3) proofs that new construction is usually larger than demolition.

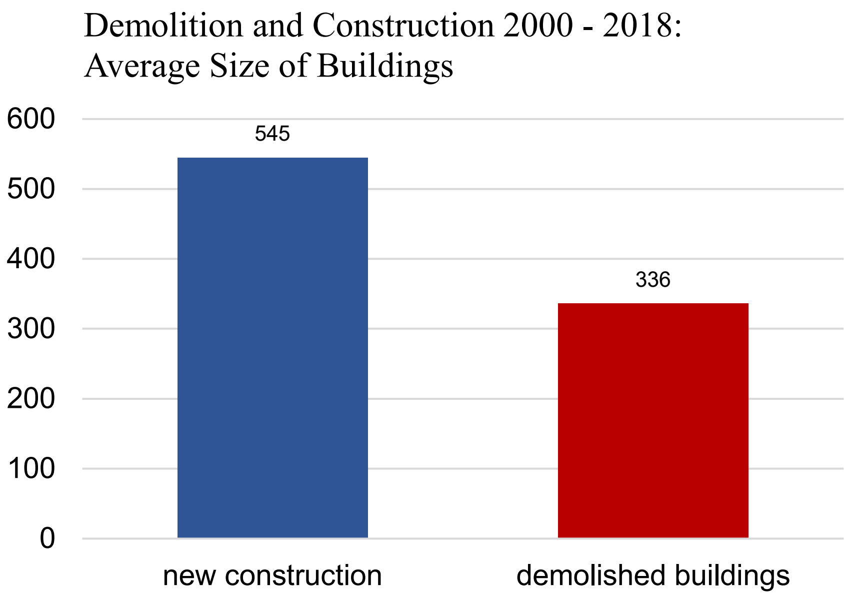
The comparison of these total numbers reflects the growth of the Finnish building stock since 2000 (Statistics Finland, 2020). Small buildings seem to make way for larger new construction which might show that one driver for demolition could be the need for larger buildings. Also, it is quite typical for growing urban areas to cause demolition due to the replacement of buildings. In the case of Tampere, it can be even expected that the replacement factor is becoming smaller. That means that new construction is expected to cause an increased amount of demolition.



Graph 4.3.2: Gross floor area of buildings construction and demolition



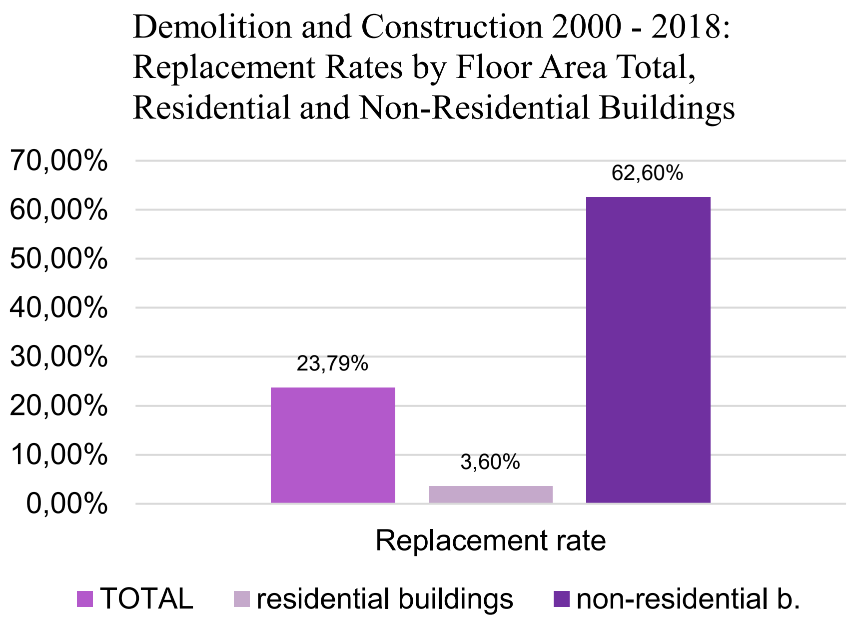
Graph 4.3.1: Number of buildings construction and demolition



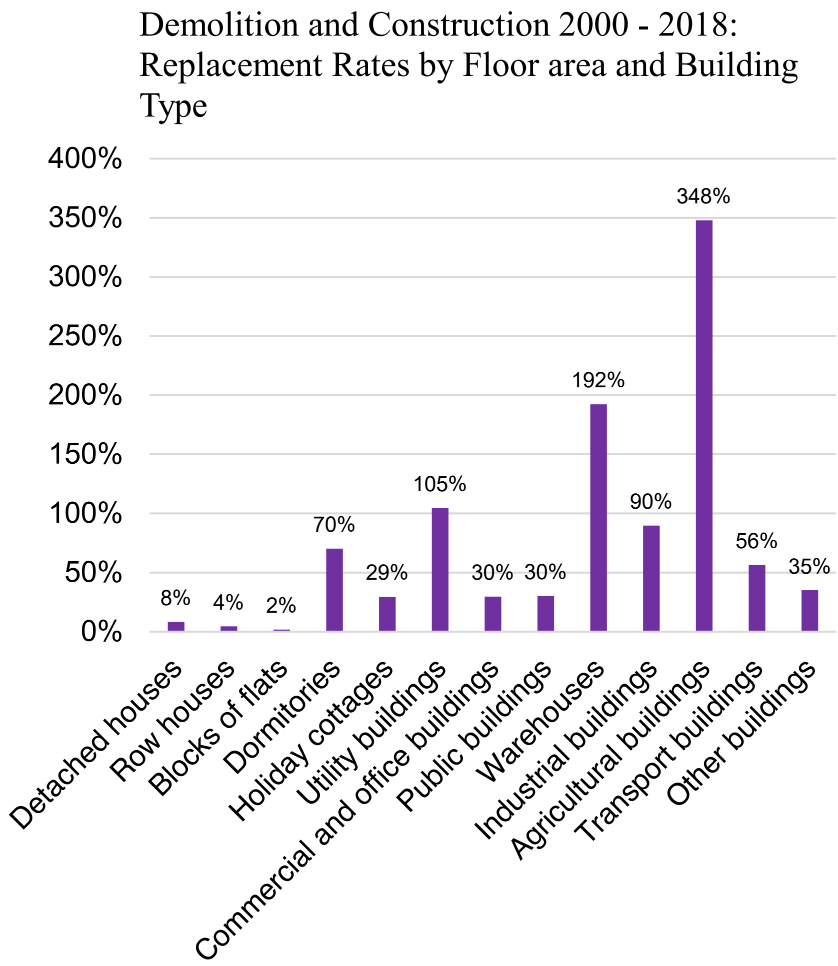
Graph 4.3.3: Average size of buildings construction and demolition

Comparing the floor area of residential and non-residential buildings (see graph 4.3.4), the replacement rate of residential buildings - with 3,60% - is significantly smaller than the replacement rate of non-residential buildings with 62,60%. The former value is the result of a very large number in new construction compared to small demolition, the latter shows almost the opposite: large demolition and medium sized new construction. In other words, every square meter of demolished residential buildings was compensated with almost 28 square meters, while every demolished square meter of non-residential buildings was compensated with only 1,60 square meters. Theoretically, 1 residential building was demolished for 6 new buildings while 1 non-residential building was demolished for only 1,52 new buildings.

It seems that there is a higher demand for residential buildings than non-residential buildings. The larger amount of demolished non-residential buildings might even indicate that those buildings were demolished to make way for both, non-residential and the large amount of new residential buildings.



Graph 4.3.4: Replacement rates total, residential and non-residential buildings



Graph 4.3.5: Replacement rates by building type

By going into more detail for each of the building types, the previously observed phenomenon is reflected almost throughout all of the building type groups (graph 4.3.5): residential buildings commonly have a lower replacement rate than non-residential buildings.

These very low replacement rates for residential buildings such as blocks of flats, row houses and detached houses shows that there is a massive need of housing units in Tampere which is little surprising as Tampere is one of the fastest growing municipalities in Finland. Looking at non-residential buildings, there are significant differences. While commercial & office, transport and public buildings are much below 100%, meaning there is a relatively high increase in floor area for those building types, demolition and new construction for industrial buildings is almost even. Looking further at warehouses, we can see that demolition is almost twice as high as new construction. All in all, it seems there is a shift from heavy industry (warehouses, industrial buildings) towards a rather service based economy (commercial & office) in Tampere. The increase in public and transport buildings is more or less in line with the increasing amount of Tampere citizens.

Average Size

Graph 4.3.6 shows how the average size of buildings has changed from demolition to new construction. Not only does the total size of new construction exceed demolition in most of the cases, also the average size of demolished buildings is often much smaller than of new buildings. By far the largest differences can be observed for blocks of flats and commercial & office buildings. With an average size of 2 244 sqm, newly built blocks of flats are 3,64 times larger than demolished ones which reflects the high demand of living space and the continuing urbanization and densification of Tampere, once again.

The average size of commercial & office buildings is 5 117 sqm. Not only are they on average the largest newly built buildings, their size has also increased by 3,63 times compared to demolished buildings of the same type which shows the trend towards more centralized commercial units.

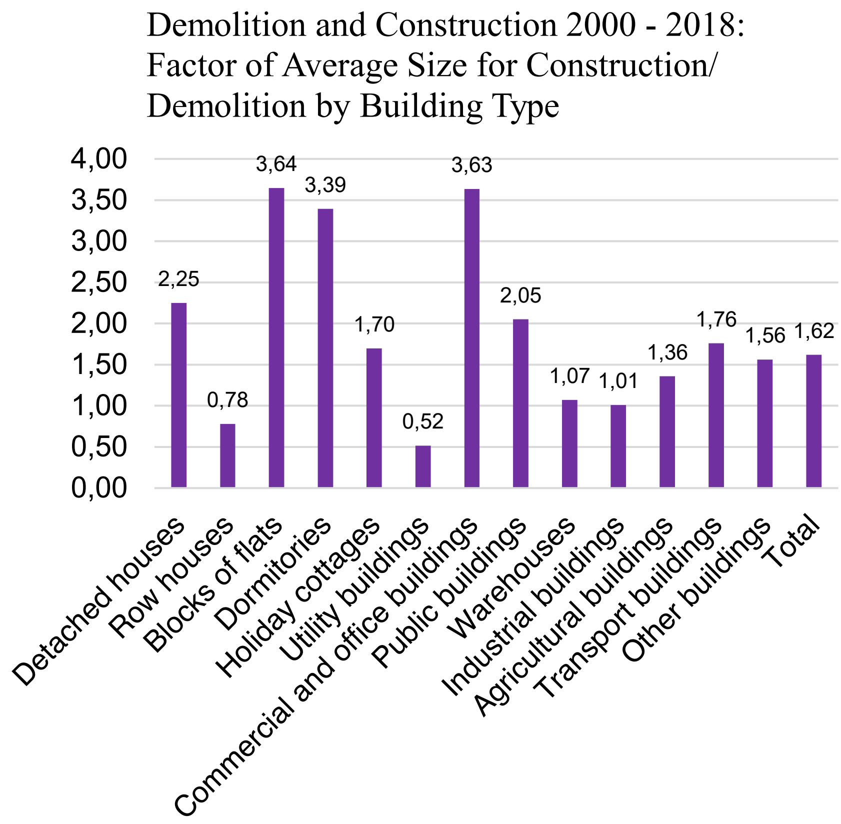
With approx. 2 times the average size of demolished buildings, public buildings' sizes haven't increased as drastically, yet corelate with the rising demand in housing and therefore rising demand in shops and services.

The average size of demolished utility buildings is almost twice the size of newly built ones. It seems that most of the functions such as sauna and storage that used to be located inside these kinds of outhouses have either vanished or moved inside the actual main buildings.

The fact that the average size of newly built detached houses is more than twice as big as for demolished ones could also be seen critically, as the size of Finnish households tends to become smaller and therefore a large amount of space and installations is shared among a relatively low amount of individuals. The apparent reduction in average size of row houses fits the image of being an oddity to the Finnish housing stock.

Another rather unusual finding are holiday cottages whose average size and total amount of new construction is almost twice as much as for demolition which seems to be a bit uncommon as cottages have the reputation to be situated in more rural areas. One possible explanation is that there might be a trend towards holiday cottages close to urban regions as these come with the convenience of short routes.

For both, warehouses and industrial buildings, the average size of demolition and new construction is almost identical, while the total number of demolished warehouses is almost double new construction. Here, we can identify the general shift from producing to service society and also, a change in location, especially towards larger traffic junctions further outside the city. Especially for the city of Tampere that used to be known for its large producing industry and working class, this shift also means a change of its identity and its appearance.



Graph 4.3.6: Comparison factor of average building size for new construction and demolition by building type

Annual construction vs. demolition

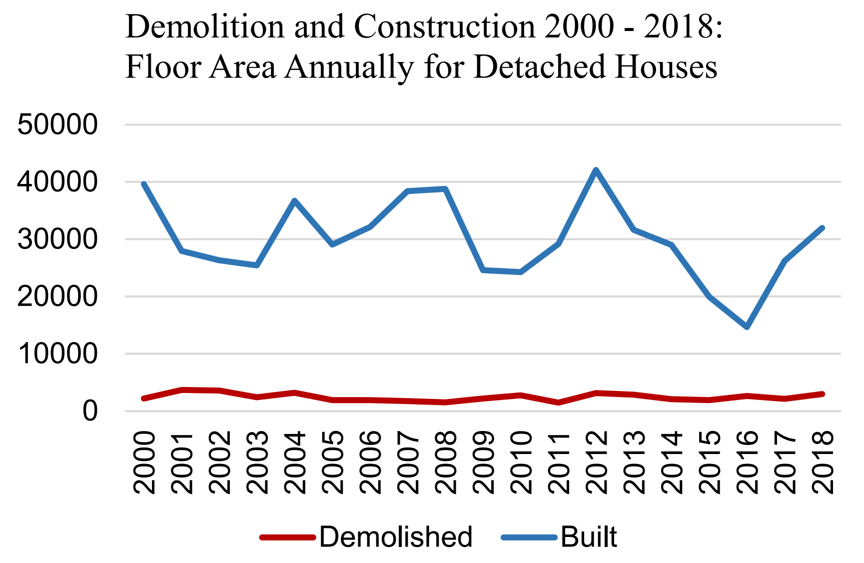
Comparing new construction with demolition annually between 2000 and 2018 by building type, one can see quite clearly that construction exceeds demolition almost every year for almost every building type. This finding can be observed particularly well for residential buildings (graphs 4.3.7, 4.3.8 and 4.3.9) with curves of newly built floor area high above demolished floor area, including some occasional peaks.

When it comes to utility buildings for example (graph 4.3.10), the curves show that construction exceeds demolition during the first couple of years, slowly narrowing towards the end of the first decade and again diverging but this time with higher demolition than new construction.

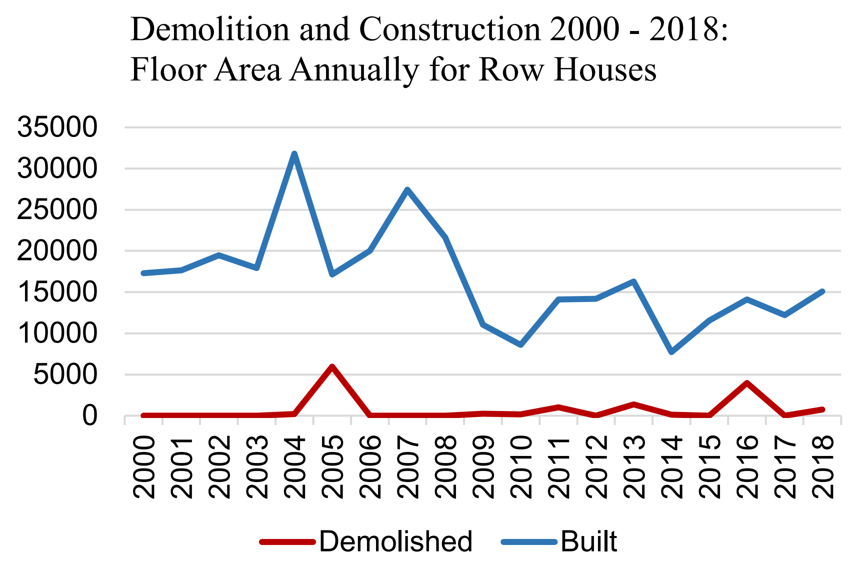
The curves for public buildings (graph 4.3.12) usually show construction exceeding demolition including few exceptions where construction dips below the mostly steady demolition curve. In 2016, both, demolition and new construction form a peak together which is quite a rare phenomenon in this study and that was subject to some further analysis. It was found out here that the timely correlation has, indeed, not been a coincidence. In 2016, the Kauppi hospital area underwent some transformation which caused demolition of an older part of the hospital and new construction during the same year.

The curves of industrial (graph 4.3.14) and transport buildings (graph 4.3.16) seem to follow a rather random pattern with occasional peaks for either demolition or new construction. Also, commercial and office buildings seem to follow no clear pattern, construction usually exceeds demolition with high points in 2009 and 2010.

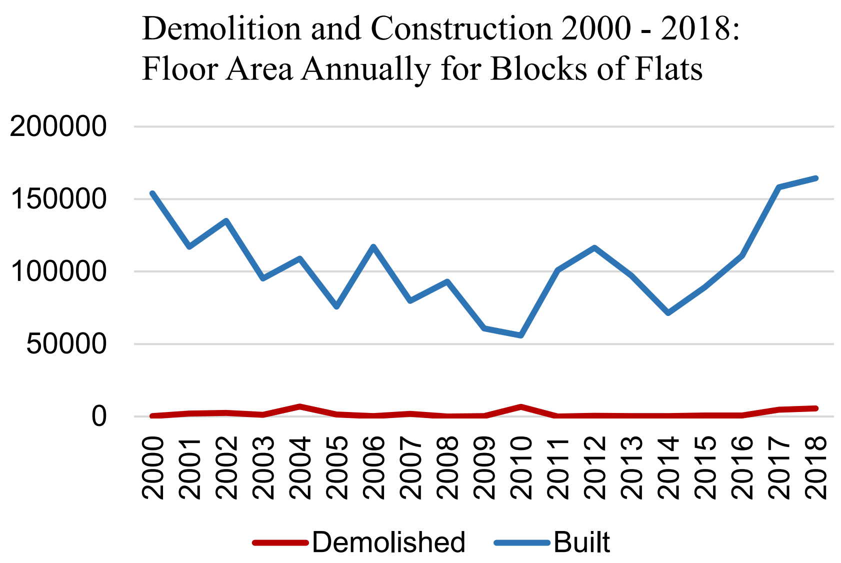
Only agricultural buildings and warehouses show higher demolition than new construction throughout the studied period which is in line with previous findings from which these building types appear to become less popular.



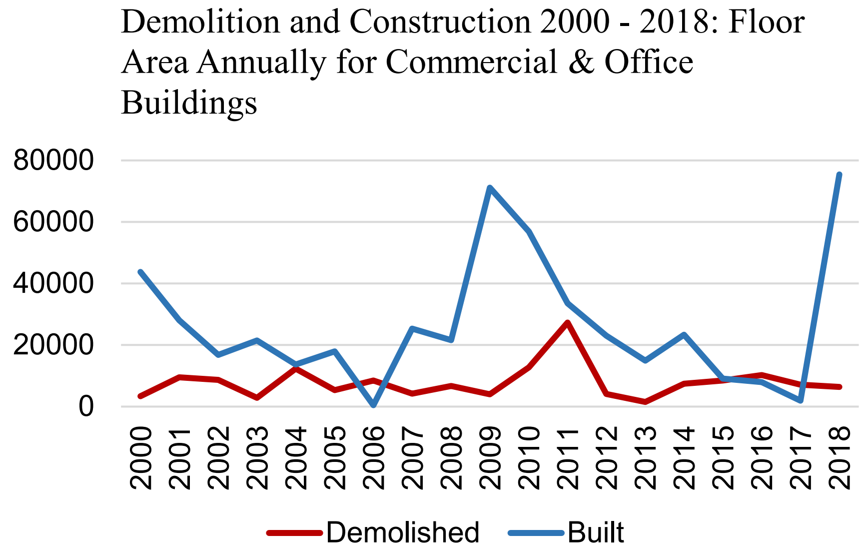
Graph 4.3.7: Demolition and construction 2000 - 2018 annually for detached houses



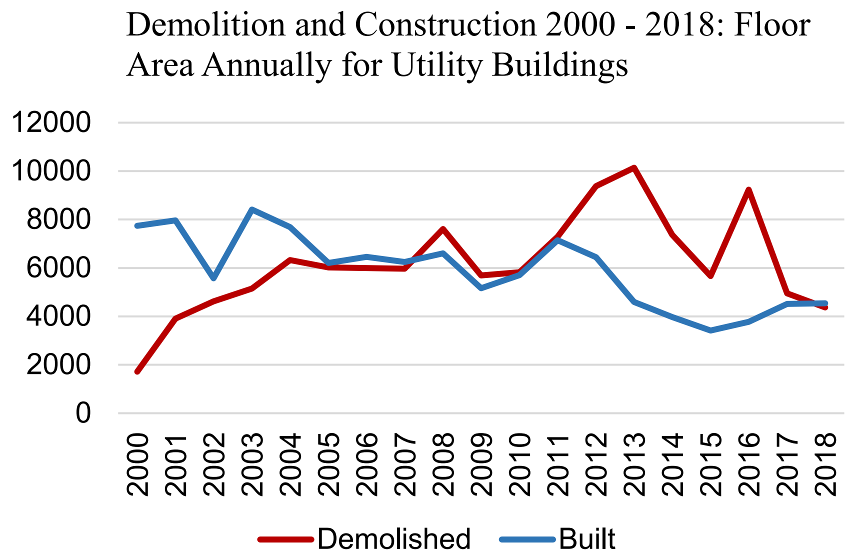
Graph 4.3.8: Demolition and construction 2000 - 2018 annually for row houses



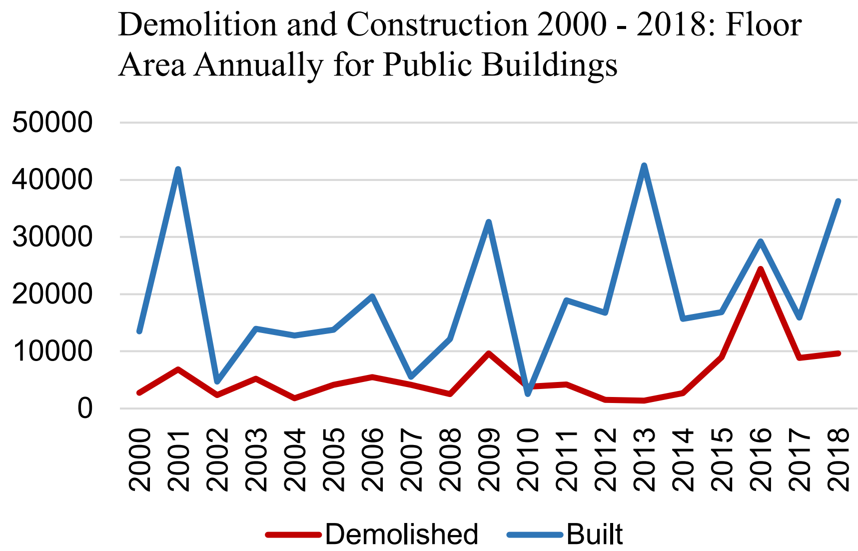
Graph 4.3.9: Demolition and construction 2000 - 2018 annually for blocks of flats



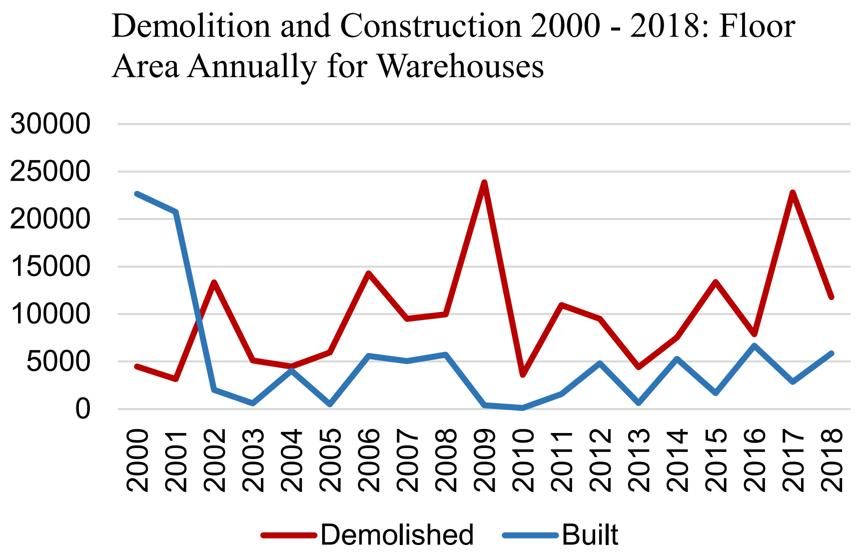
Graph 4.3.11: Demolition and construction 2000 - 2018 annually for commercial & office buildings



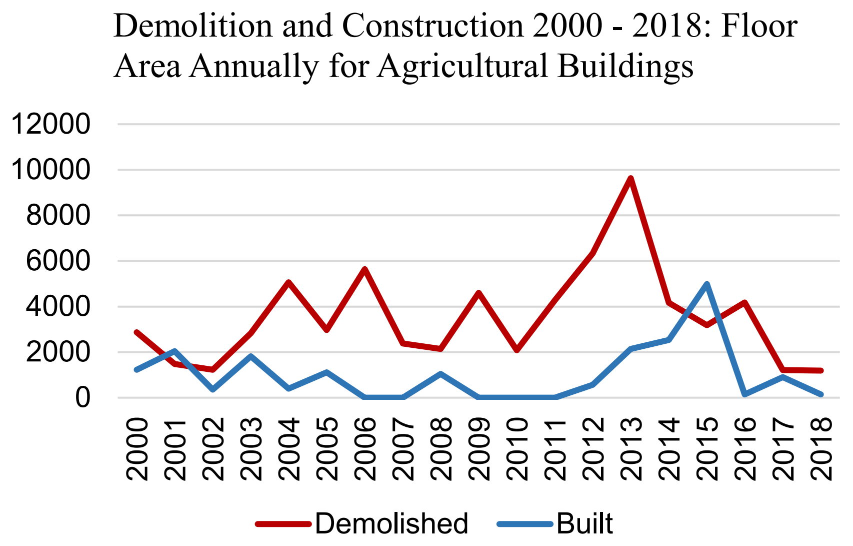
Graph 4.3.10: Demolition and construction 2000 - 2018 annually for utility buildings



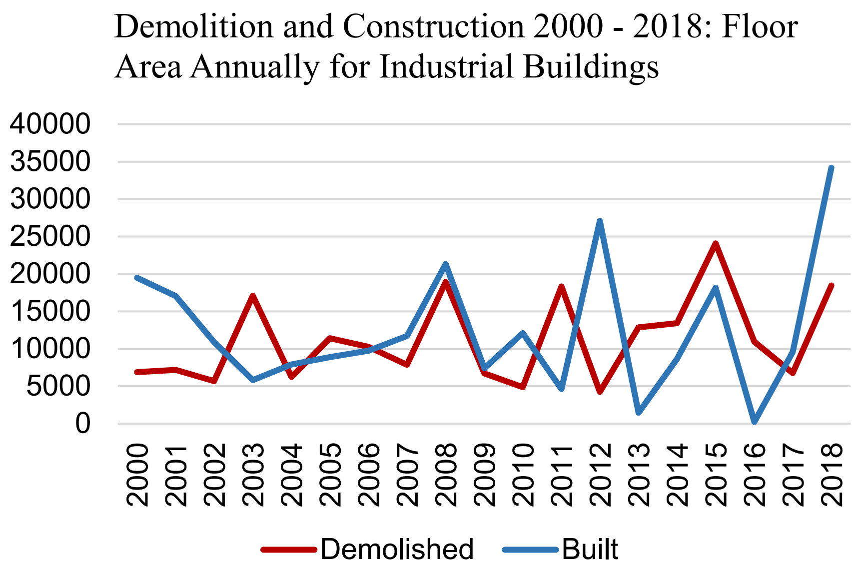
Graph 4.3.12: Demolition and construction 2000 - 2018 annually for public buildings



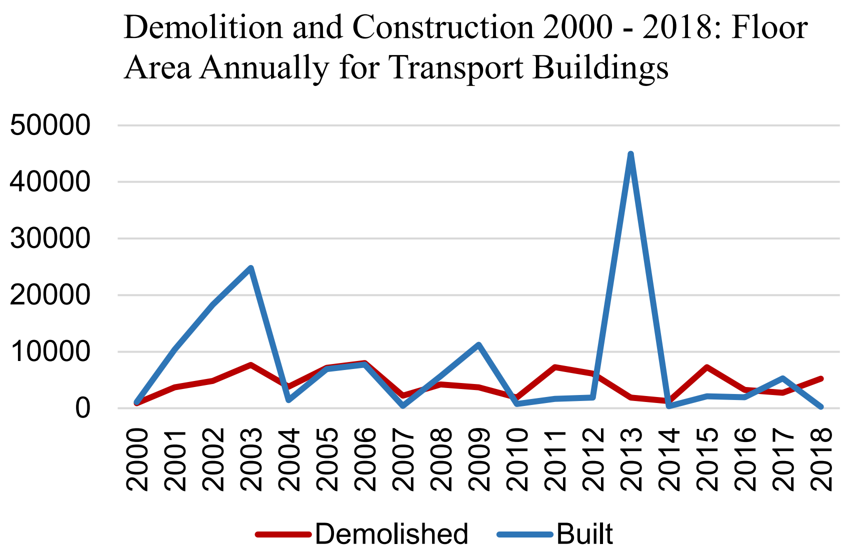
Graph 4.3.13: Demolition and construction 2000 - 2018 annually for warehouses



Graph 4.3.15: Demolition and construction 2000 - 2018 annually for agricultural buildings



Graph 4.3.14: Demolition and construction 2000 - 2018 annually for industrial buildings

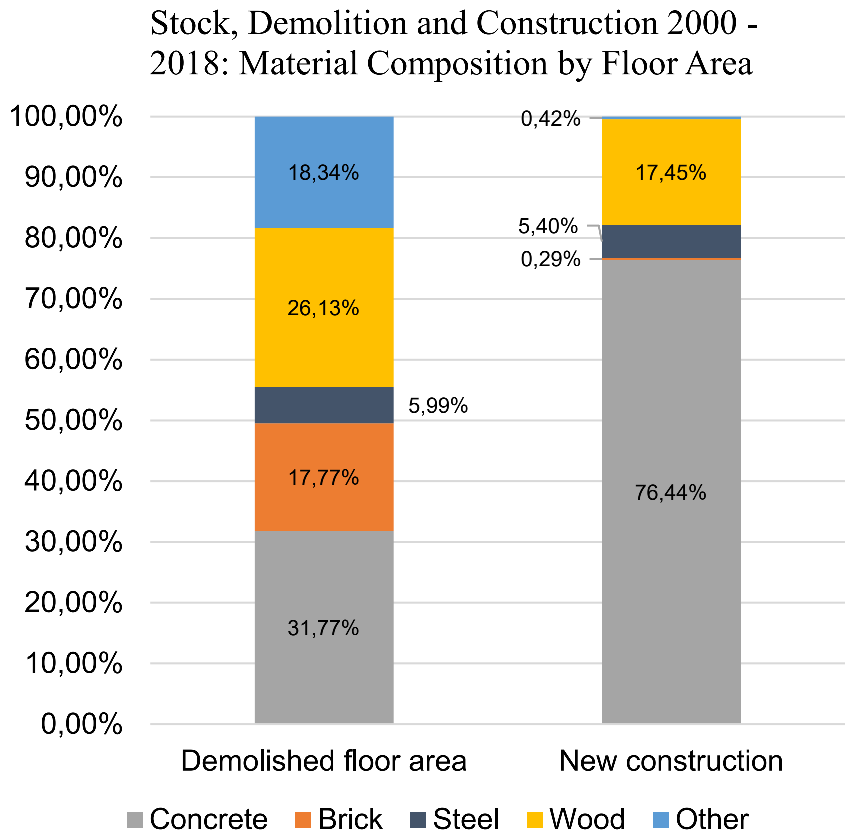


Graph 4.3.16: Demolition and construction 2000 - 2018 annually for transport buildings

Material Composition

Directly comparing the material composition of demolished and newly built building square meters (graph 4.3.17), one can see that there is an overwhelming majority of concrete (>75%) and wood (17%) that replace either brick (18%), wood (26%) or concrete (32%) as building materials.

All in all, it seems that the building stock in Tampere is going through a transformation away from brick and wood towards especially concrete and steel. Again, the high embodied energy of those mentioned latter needs to be considered more critically. An increase in carbon-intensive construction materials requires a more careful treatment with the building and material stock in order to reduce its embodied emissions.

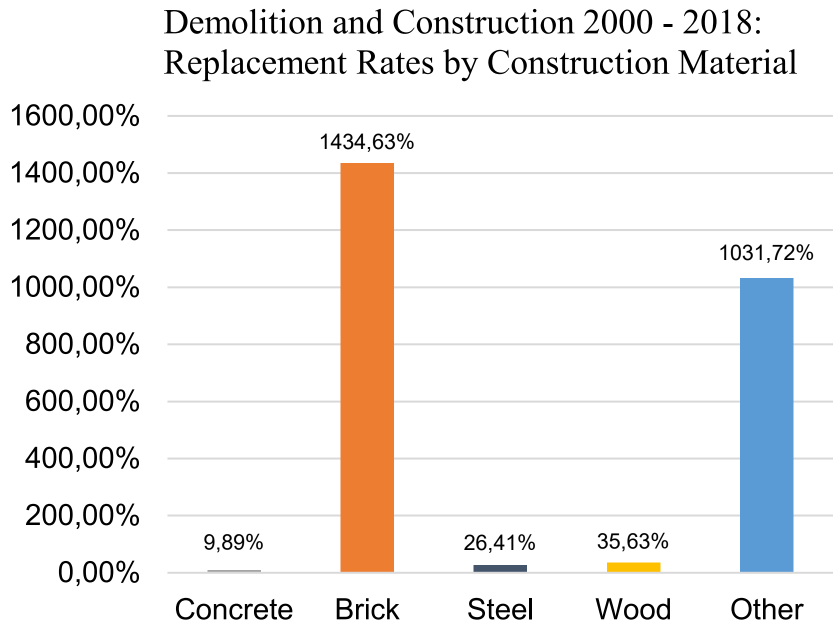


Graph 4.3.17: Material composition of demolition and new construction

Graph 5.3.18 shows the replacement rates by construction material. The low replacement rate of concrete buildings reflects the massive increase of concrete as a construction material. Also, steel shows a large increase, for every demolished square meter of steel buildings, four square meters were built.

The amount of floor area of wooden buildings has also increased. Construction has been approx. three times the amount of demolition. Even though the total numbers are increasing, the share of wooden buildings in the building stock is slowly decreasing due to the massive boom in construction with concrete.

The numbers of brick buildings, however, show a massive decrease in construction. The size of demolished floor area is around 14 times higher than new construction. In other words, for every newly built square metre made of brick, 14 were demolished. The shrinking popularity of brick as a construction material is mainly due to its laborious and hence expensive nature. Compared to concrete, brick is a very costly building material to build with. On top of that, it is more difficult to reach the Finnish energy standards when building with brick.



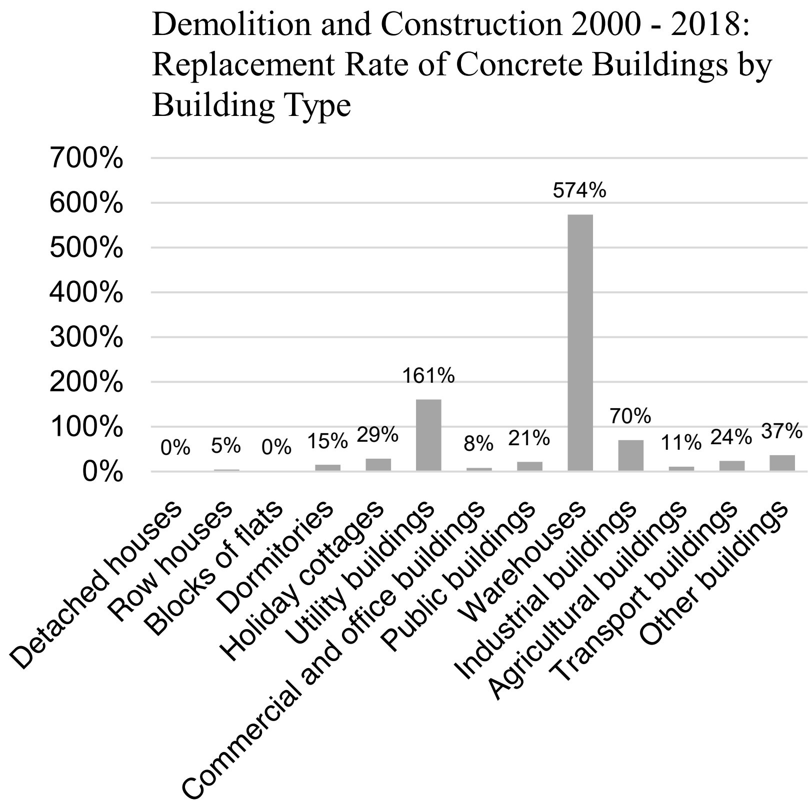
Graph 4.3.18: Replacement rates by construction material

The following graphs show the replacement rates by main construction material and building type. A replacement rate below 100% means that there was a larger size of new construction compared to demolition. Around 100% means that demolition and construction were roughly equal, while a replacement rate above 100% overall means shrinkage.

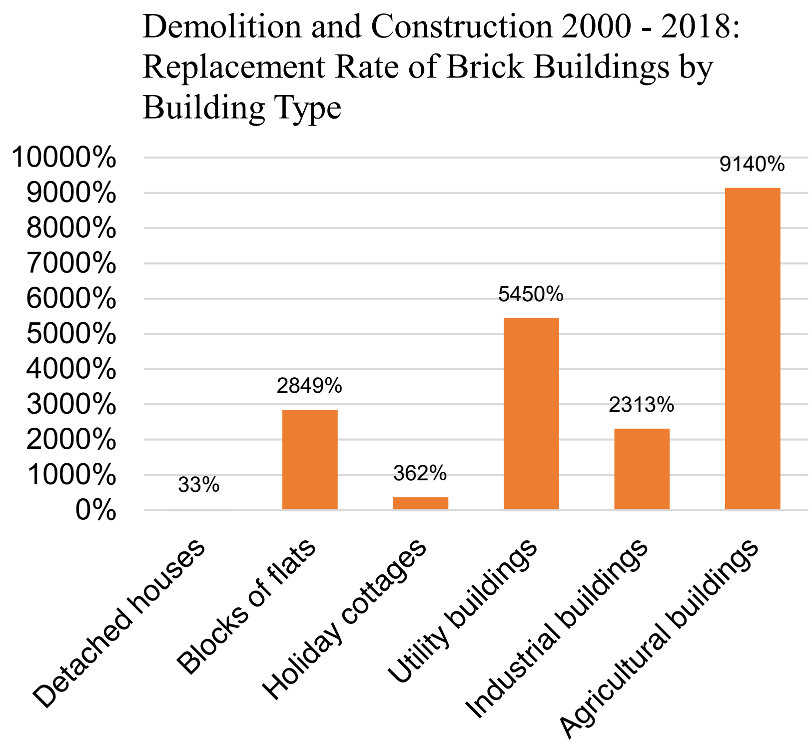
Going into more detail for each of the building types, one can see that there is massive increase throughout almost all the building types for concrete (graph 4.3.19). It seems that only utility buildings, for which concrete is a rather untypical construction material, and warehouses, which have generally shown a high demolition rate, were made less of concrete. The graph reflects the increased popularity for concrete throughout almost all the building types. In order to maintain the material value, it would be interesting to investigate whether concrete elements have the potential of being reused across building types.

While brick is becoming less popular throughout the building type groups except detached houses (see graph 4.3.20), steel buildings show a slight increase except for agricultural and transport buildings (see graph 4.3.21).

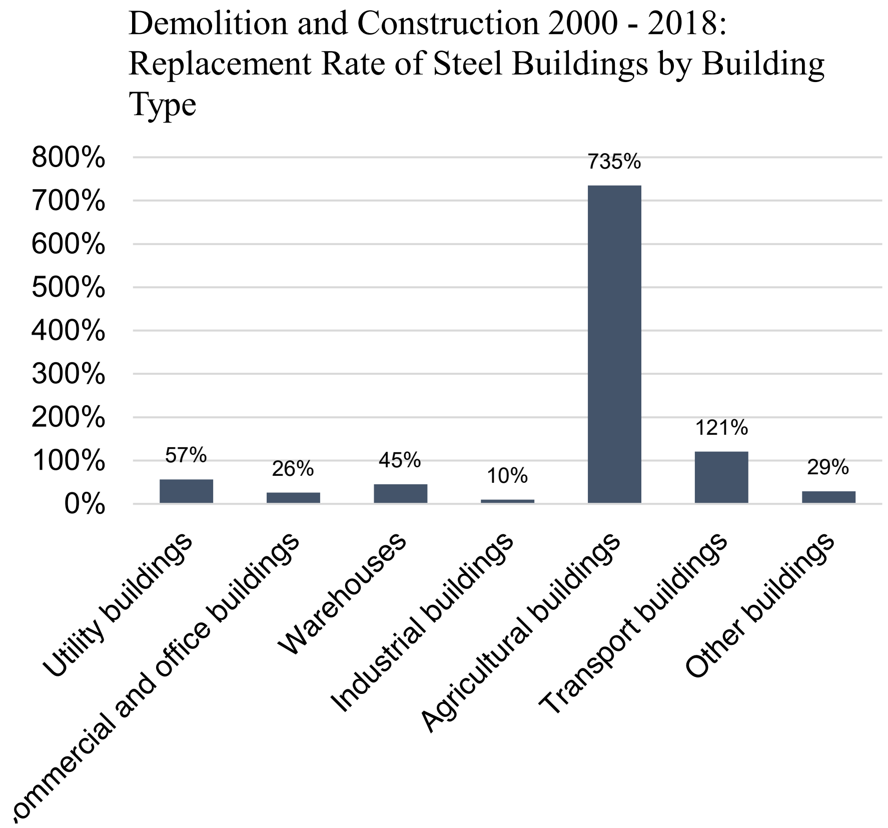
The replacement rates of wood as a construction material are of a rather diverse nature (see figure 4.3.22). The building types which are traditionally made of wood like detached houses, holiday cottages, utility buildings (like outhouses and saunas) and blocks of flats show an upward trend. The new construction of row houses as a relatively young building typology shows an increased use of wood as well. The increase of public and industrial buildings made of wood might also be due to the fact, that there is just a very small amount of those buildings that could be demolished. The remaining building types show a decrease in wood as their main construction material which is quite unfortunate considering the material's low embodied emissions.



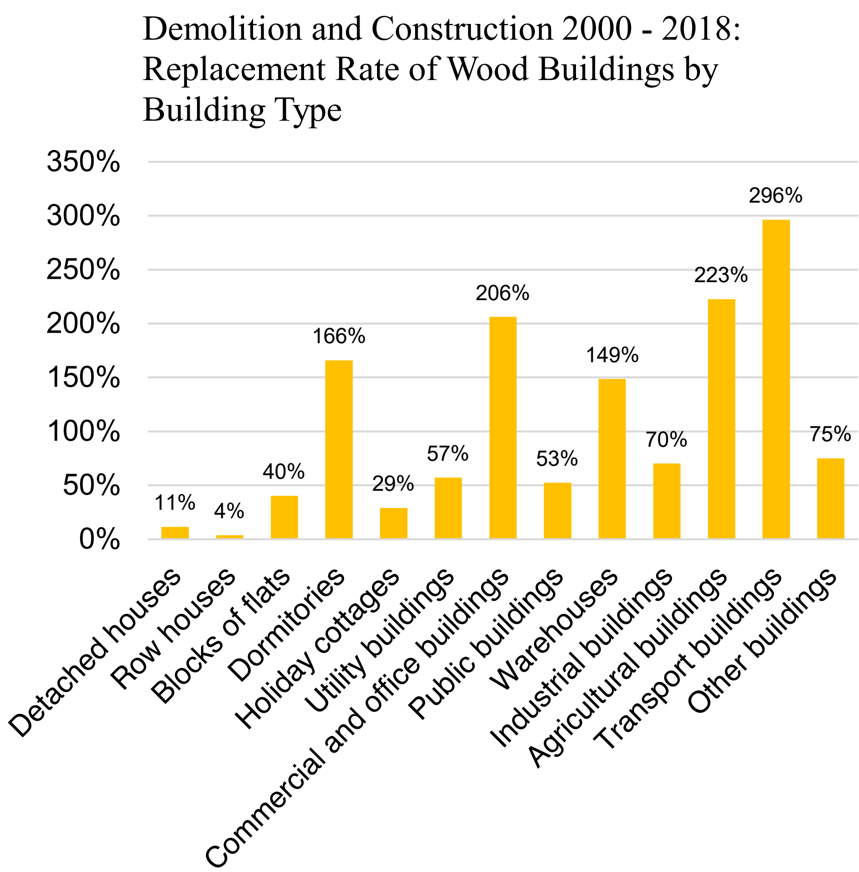
Graph 4.3.19: Replacement rates of concrete buildings by building type



Graph 4.3.20: Replacement rates of brick buildings by building type



Graph 4.3.21: Replacement rates of steel buildings by building type



Graph 4.3.22: Replacement rates of wood buildings by building type

Spatial Distribution

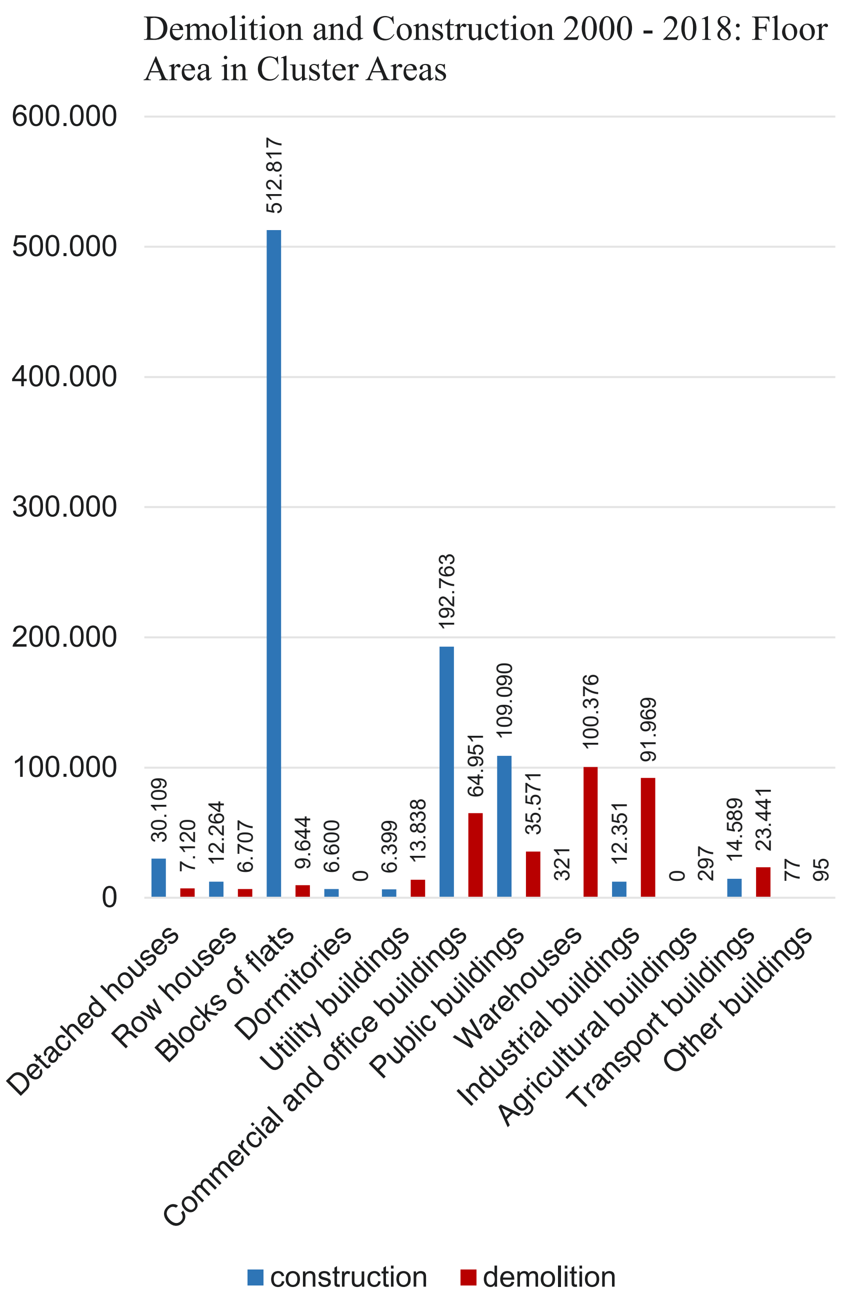
The following map 4.3.23 is a merger of the demolition and the construction map. The blue squares symbolize areas that have a majority in new construction while the red squares show areas that have a relatively high demolition in comparison to construction. The purple squares show areas, where new construction and demolition overlap, meaning areas where we can potentially find replacement of buildings. The darker the colour, the more pronounced is each of these phenomena.

In total, areas of replacement comprise over 350 000 sqm of demolished floor area and almost 900 000 sqm of new construction. In these areas, almost 35% of total demolition and around 20% of total new construction can be found. In other words, between 2000 and 2018, in 25% of demolished floor area, construction followed, which leads to the conclusion that land use changes were one of the drivers for demolition.

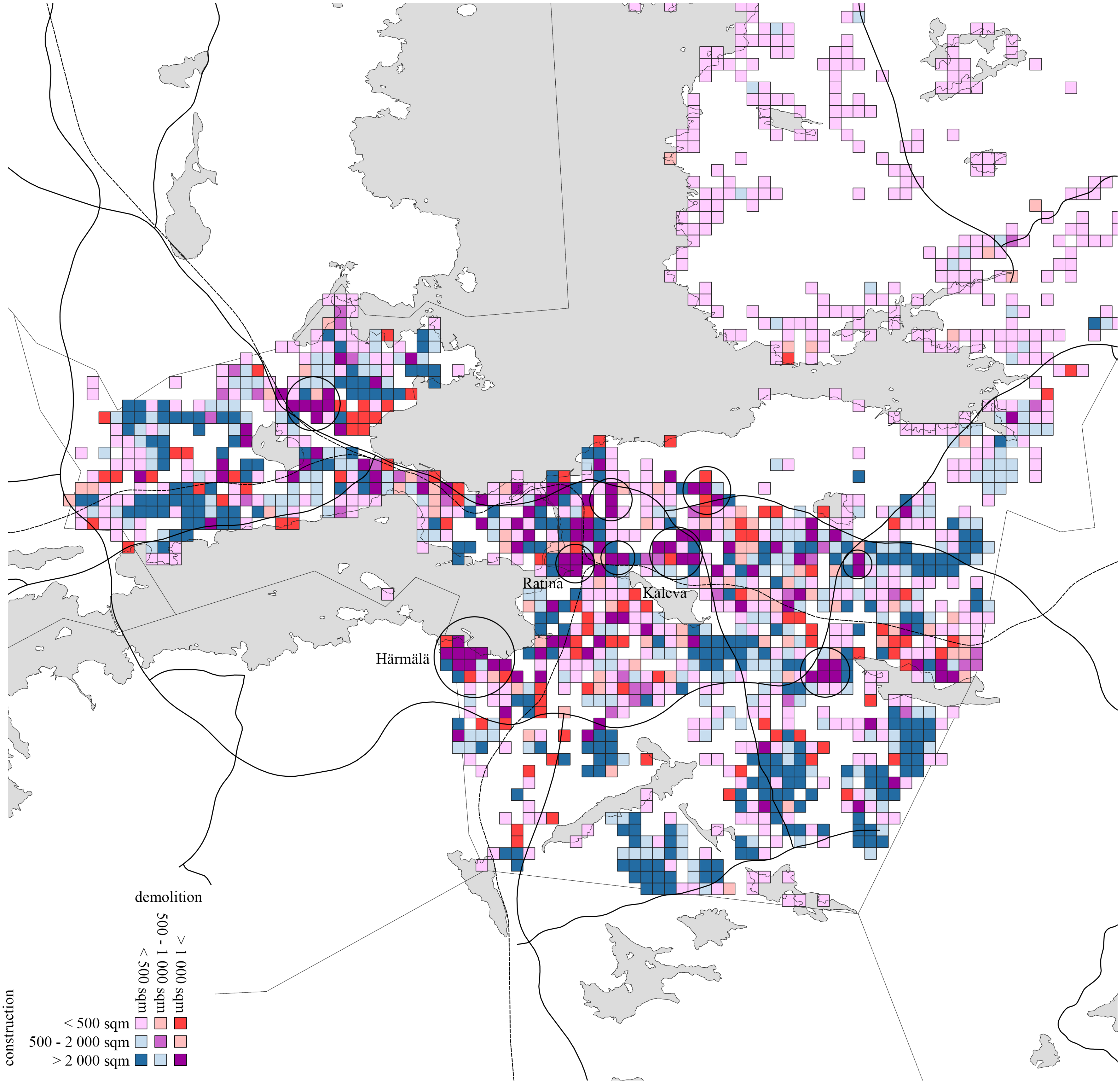
The following zoom in areas Kaleva, Ratina and Härmälä give an idea of what replacement in Tampere often looked like.

Interestingly, the replacement clusters reflect the overall development of construction and demolition in Tampere (graph 4.3.24). The overwhelming majority of newly built floor area is used for blocks of flats. Also, commercial & office and public buildings show a large increase while especially warehouses, industrial buildings and commercial & office buildings were target of demolition.

In other words, in Tampere, especially warehouses, industrial, public and commercial & office buildings were replaced by either blocks of flats, commercial & office buildings or public buildings. This finding proofs the assumption that buildings get demolished because of land use change. This finding is especially valuable when discussing the importance of functionally adaptable buildings. Theoretically, those demolition patterns can be avoided by identifying and seizing the natural transformation potential of existing buildings. Buildings have the capability of changing their functional and spatial properties. In order to avoid demolition for the future building stock, buildings must be designed in order to be responsive on possible future scenarios. That means that buildings have to be ready for functional and spatial transformation in order to avoid them being demolished to get replaced (in chapter 6, these issues are discussed in more detail).



Graph 4.3.24: Total demolition and new construction in cluster areas



Tampere replacement 2000 - 2018

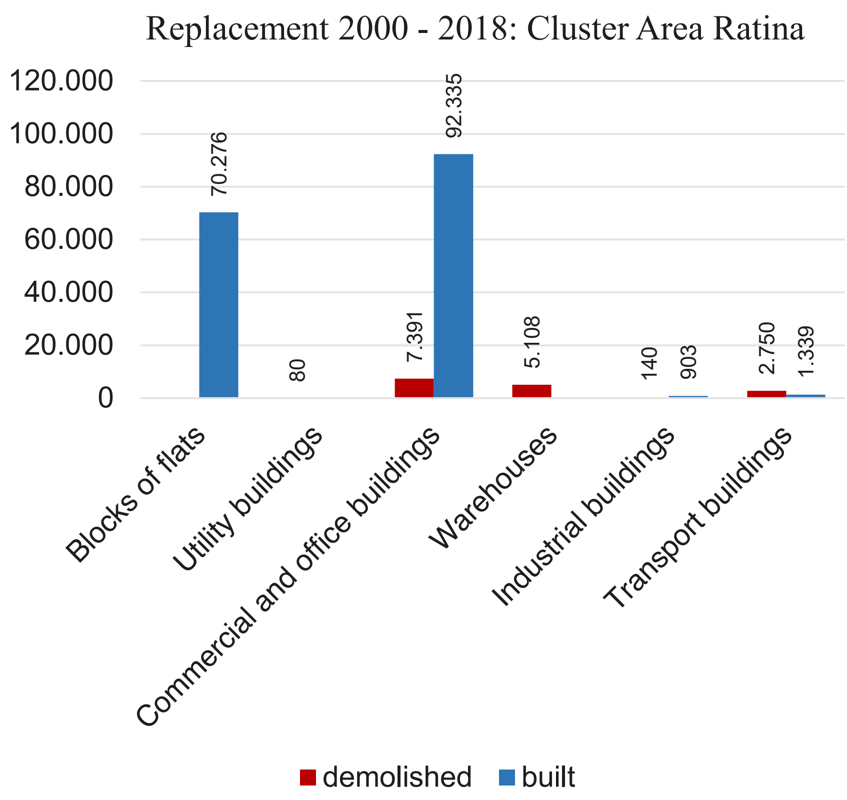
scale | 1:85 000

Map 4.3.23: Grid of total floor area of replacement

Cluster Ratina

One of the most prominent examples of spatial replacement in Tampere might be the Ratina area (map 4.3.25). Due to new development plans, 15 469 sqm floor area was demolished. Almost half of it, i.e. over 7 000 sqm meters were used as commercial and office buildings. Warehouses make more than 5 000 sqm of demolition in this area, followed by transport buildings with a share of over 2 500 sqm (graph 4.3.26). Until 2018, new construction has accumulated to 164 853 sqm. The Ratina shopping mall and other commercial and office buildings make 92 335 sqm of new construction while an ensemble of blocks of flats along the northern side of the Viinikanlahti bay makes 70 276 sqm.

The Ratina area is a good example of what replacement in the urban area looks like. Buildings which were either too small or functionally inappropriate were wiped out to make way for intensive new construction. This behaviour is exemplary for urban developments including Amuri in 1970s and 1980s and can be expected to affect central locatins also in the future such as buildings affected by the Eteläpuisto masterplan.



Graph 4.3.26: Demolition and new construction in cluster area Ratina by building type

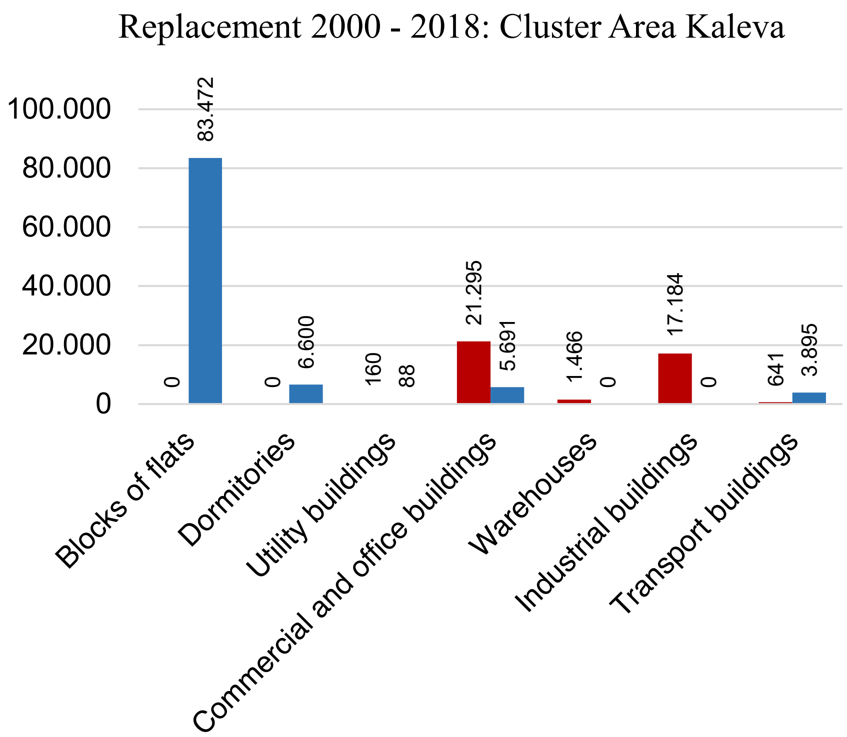
Ratina cluster, replacement 2000 - 2018 | existing buildings | new construction | demolition | scale | 1:5 500

Map 4.3.25: cluster area of replacement Ratina

Cluster Kaleva

Situated east, close to the city center, is Kaleva (map 4.3.27). Especially the area located at the main road Sammonkatu is dominated by characteristic 1950s and 1960s blocks of flats. Until the 2000s, the south-eastern part of the area was dominated by mainly low-rise commercially and industrially used buildings. In the early 2000s, a total of 40 746 sqm of buildings were demolished, most of it consisted of the aforementioned buildings types: More than 21 000 sqm commercial & office buildings, 17 000 sqm industrial buildings, almost 1 500 sqm warehouses. In the still ongoing process of replacement, 99 746 sqm of new floor area have been built in this area. The large of majority (almost 83 500 sqm) consists of blocks of flats but also 6 600 sqm dormitories, more than 5 500 sqm for commercial & office use and almost 4 000 sqm of transport buildings were built in the area (graph 4.3.28).

Kaleva is perhaps one of the most distinct replacement areas. Here, new development was easily identified as one of the key drivers for demolition, not only spatially but also chronologically. Construction of new buildings was found out to be following the demolition of previously existing buildings. In chapter 6.3, the area is presented in more detail and given an alternative plan based on demolition and new construction.



Graph 4.3.28: Demolition and new construction in cluster area Kaleva by building type

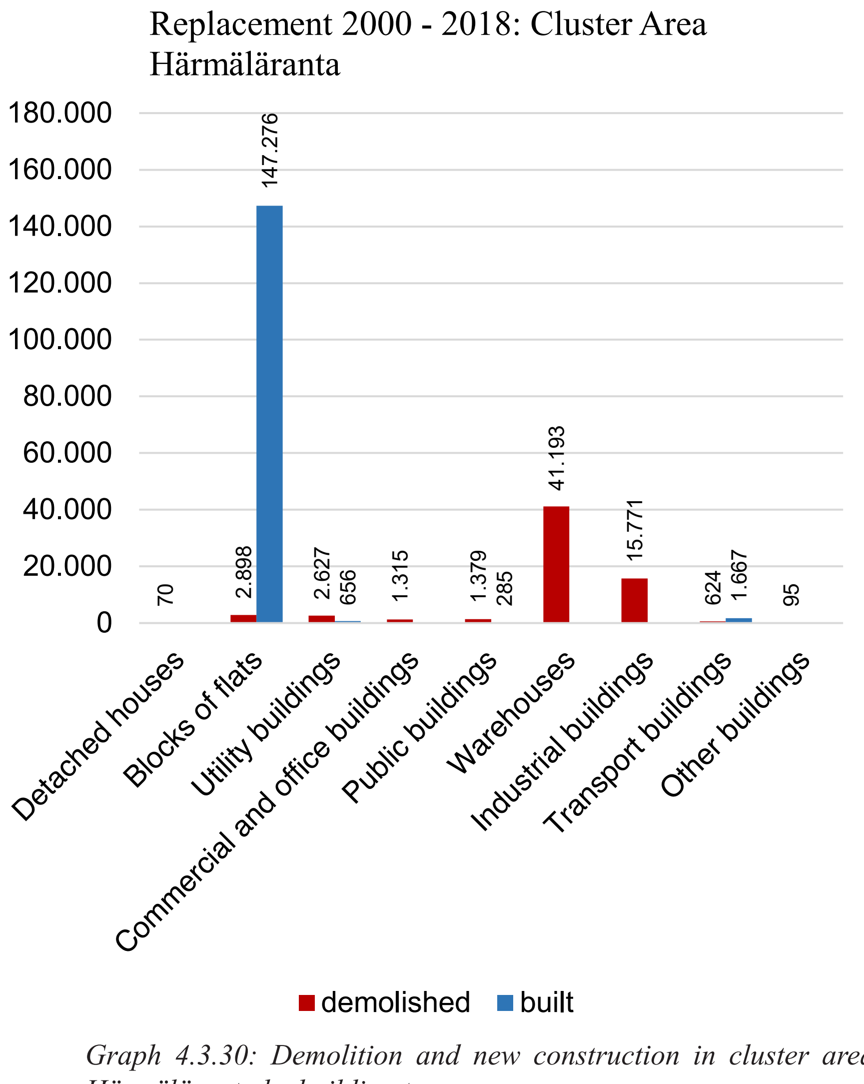
Kaleva cluster, replacement 2000 - 2018 | existing buildings | new construction | demolition | scale | 1:5 500

Map 4.3.27: cluster area of replacement Kaleva

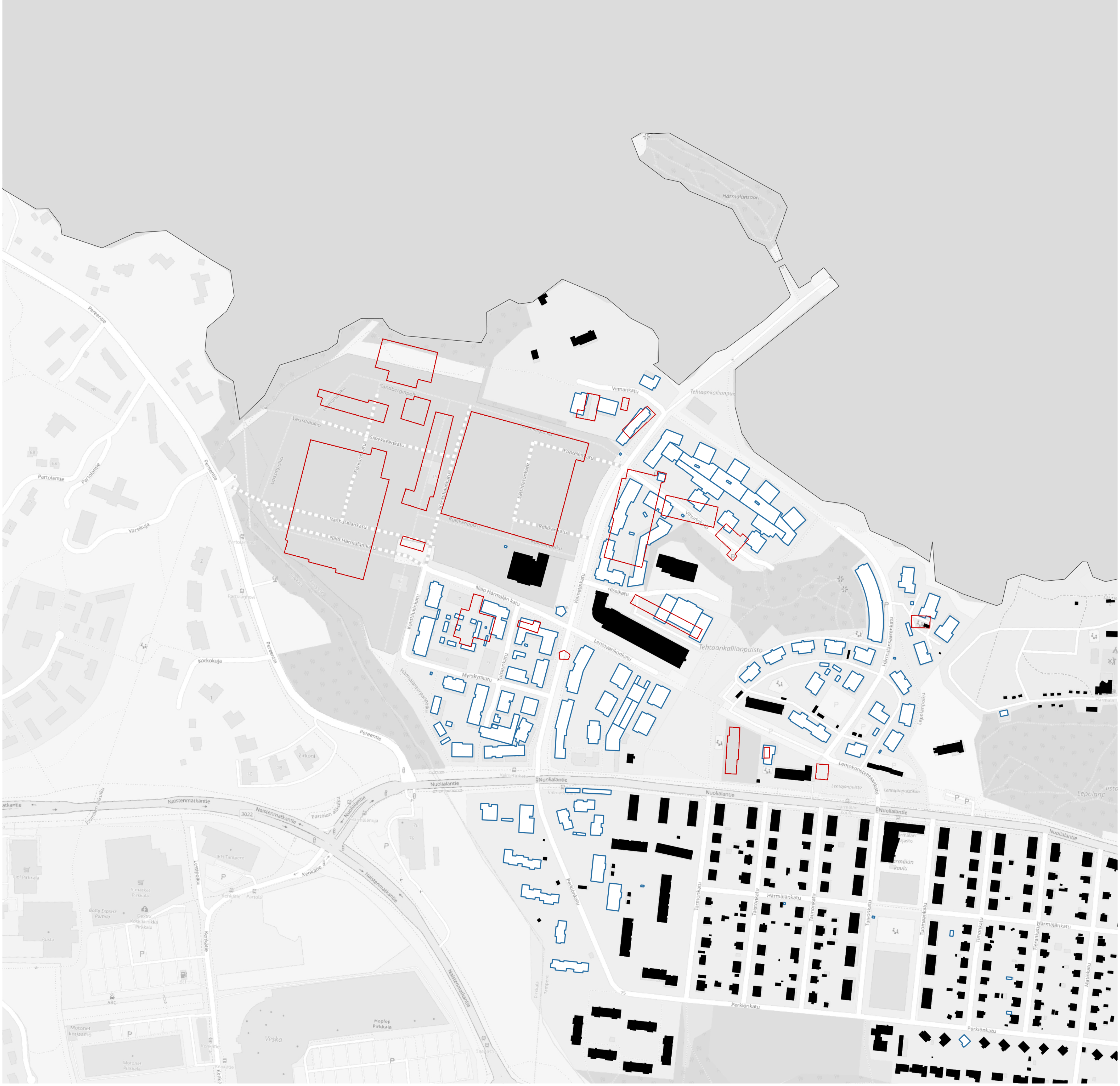
Cluster Härmäläranta

South of the city center, in close proximity to Pyhäjärvi is the area of Härmälä (map 4.3.29). Close to the lake side, at Härmäläranta lies an industrial area that, since the 2000s, has been subject of large demolition. In total, 65 972 sqm of built floor area was demolished of which around 41 000 sqm were used as warehouses (graph 4.3.30). More than 15 000 sqm used to be industrial buildings and almost 3 000 sqm blocks of flats. Also, more than 2 500 sqm of utility buildings were demolished. The area is target of an ambitious development plan of a new residential area that, until 2018, resulted in almost 150 000 sqm of new construction, more than 147 000 sqm of which are blocks of flats.

The area is one of the more ambitious urban transformations in Tampere. The new urban plan includes a variety of sustainability aspects such as biodiversity and mixed use functions with a relatively high level of flexibilty. Despite these efforts, it has failed to consider existing buildings in its planning which caused one of the biggest mass demolitions in the city.



Graph 4.3.30: Demolition and new construction in cluster area Härmäläranta by building type



Härmälä cluster, replacement 2000 - 2018 | existing buildings | new construction | demolition | scale | 1:5 500

Map 4.3.29: cluster area of replacement Härmäläranta

4.4 Building Stock

The building stock of Tampere is of high significance as it is the reserve of (construction) materials, i.e. potential resources. An analysis of those buildings means to get an understanding of the materials that are stocked in the urban mine.

The Tampere building stock in 2018 consists of 43 637 buildings, which make up a total of 19 040 046 square meters gross floor area. Graph 4.4.1 shows that the building type with the largest share, is blocks of flats with 39%. Detached houses make almost 14% of total existing floor area and commercial and office, public and industrial buildings each between 10% and 11%. Looking at the numbers of buildings, one can see that detached houses (16 721 buildings, i.e. 38%) and utility buildings (11 725 buildings, i.e. 27%) are by far the most common buildings. Far behind that come blocks of flats which make 9%, holiday cottages make 8% and row houses make 7%.

The graph highlights the significant differences between the building types, their numbers and total floor area. Certain building types like commercial & office, public and industrial buildings have very low numbers of buildings while their total built floor area is rather substantial. Other types like detached houses, holiday cottages and utility buildings show quite the opposite phenomenon. These buildings occur plenty, their total floor area however, is rather insignificant or even neglectable. For example, detached houses and utility buildings that accumulate to over 65% of the whole building stock make only 15% of the total floor area in Tampere. In conclusion, the size of buildings varies notably between the different building types (graph 4.4.2). Even though, the size of a building is not the only indicator for its material intensity (other factors such as spatial properties, technical requirements, etc. play important roles), buildings which are of a significant size need to be treated with care in order to preserve their material value. Blocks of flats for example are, based on the amount of gross floor area, the largest material reservoir in the building stock of Tampere. Measures to protect their material values need to be of high priority in a circular economy. Strategies for small buildings that appear in a large quantity on the other hand, can rather focus on quantitative approaches than the individual building.

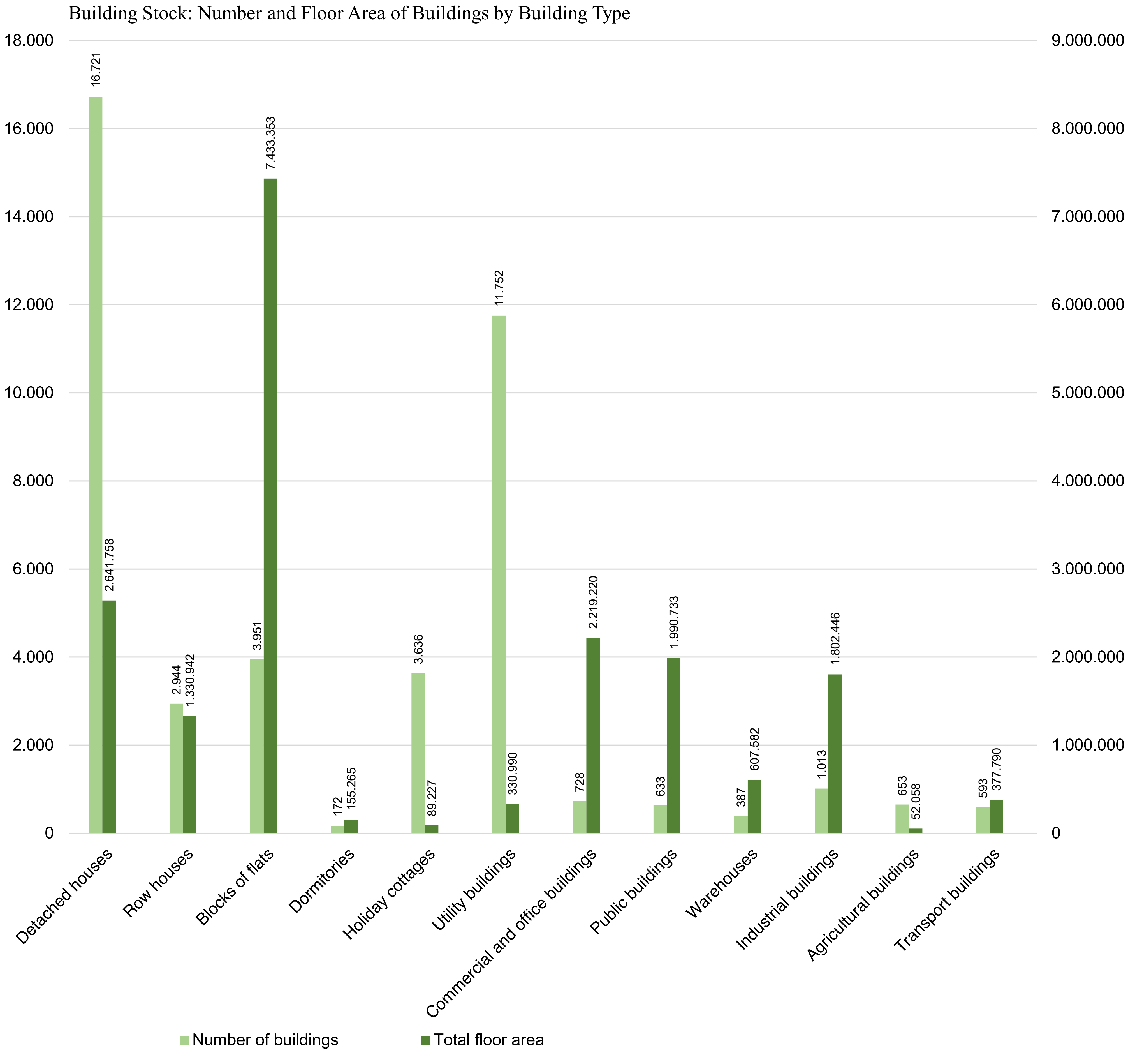
From construction and demolition patterns, the already very low numbers of warehouses and agricultural buildings can be expected to shrink even further. Especially those remaining ca. 600 000 sqm of warehouses in the building stock are threatened to get demolished. In order to save their materials, it would important to identify whether those buildings could be adapted or rather, whether the building components could be reused for the new construction of other building types.

On the other hand, the already large share of blocks of flats, row and detached houses can be expected to continuously grow. Currently, it doesn't seem that those residential building types are at any risk of getting demolished, nevertheless it would be wise to start shifting towards a building stock that consists of flexible, transformable and adaptable buildings that can be disassembled and reused in order to react on any possible future scenario that might result in demolition.

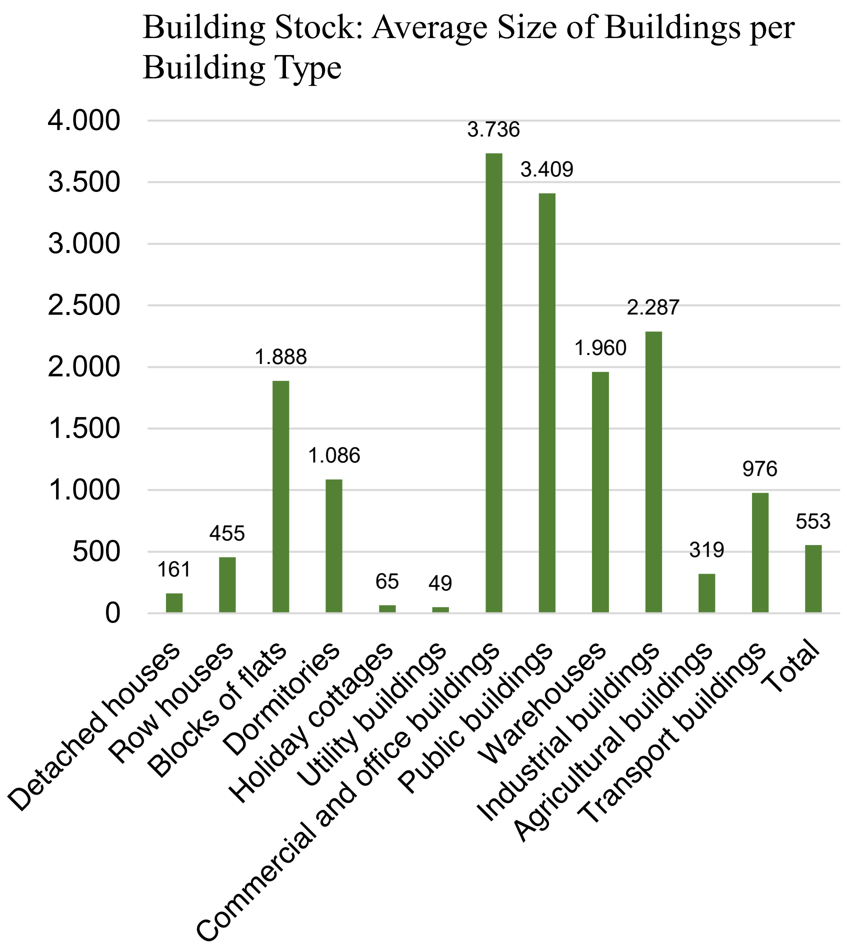
Average size

Graph 4.4.2 shows the large differences between the average sizes. Commercial & office and public buildings are by far the largest building type groups, followed by industrial buildings and warehouses. Blocks of flats are by far the largest residential building type, holiday cottages are the second smallest building type and detached houses are just barely above that. The graph proofs previous assumptions based on number and floor area of buildings. Considering buildings as material reserves, some of the building type groups appear to be more important to consider than others. However, the average size of buildings is no reliable information for the material intensity of buildings. To better assess the amount of materials that are stocked in each of the building types, Material Intensity Indicators have to be created.

New buildings have usually been larger than demolished ones. From current construction trends, it can be expected that especially residential buildings will become larger. While commercial & office buildings have become significantly larger in size, newly built public and industrial buildings show a downward trend. Previous findings have shown that too small buildings got demolished to make way for larger buildings of the same function. Knowing that especially new public and commercial & office buildings are larger than the existing ones, leads to the assumption that those buildings may become target of demolition due to their size. Even though blocks of flats have rarely been demolished, the average size of new construction has been significantly higher than of the existing stock. In order to react on the increased spatial requirements of new buildings, it will become necessary to assess the capability of the existing buildings to get extended and to design buildings that allow infill, e.g. extension by adding floors.



Graph 4.4.1: Building stock by total numbers, total size and building type

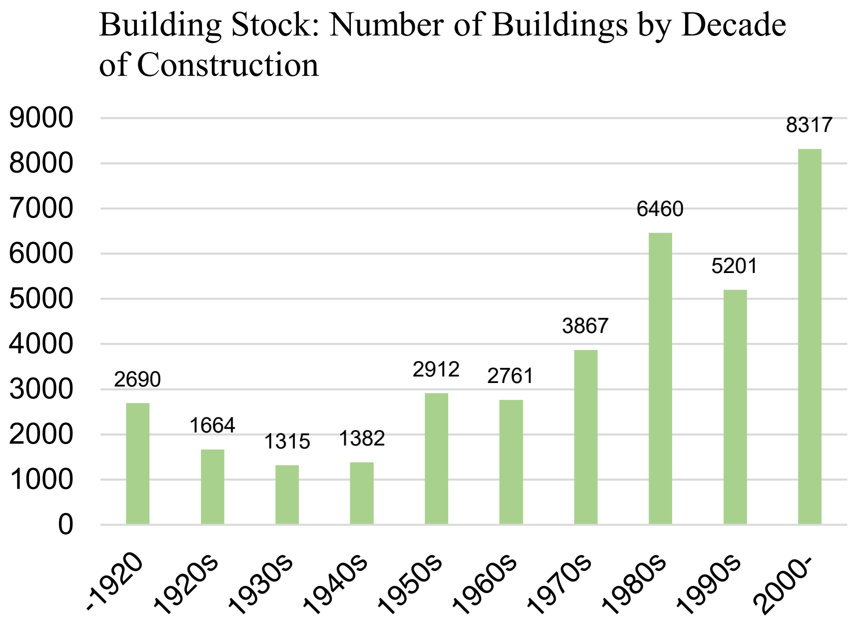


Graph 4.4.2: Building stock average size of buildings by building type

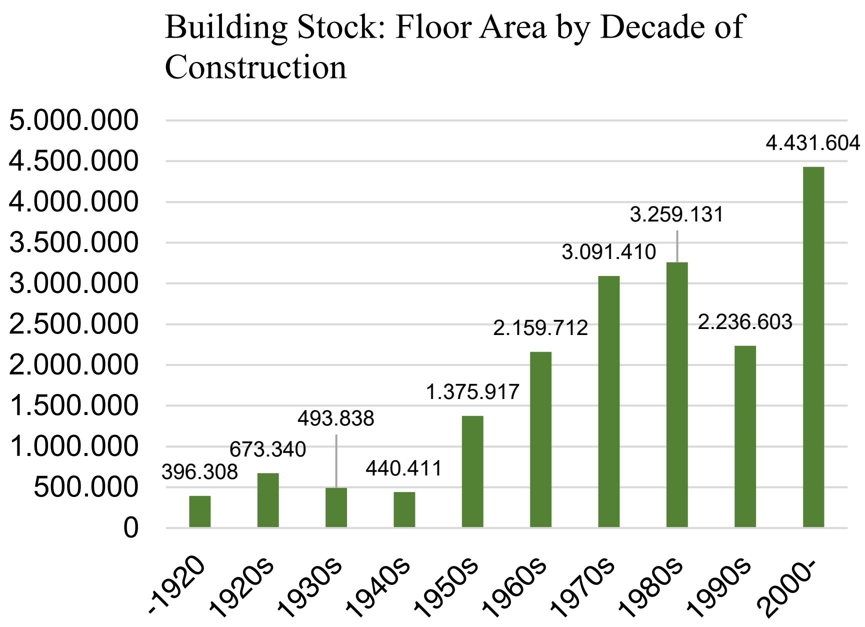
Construction Decades

When looking at the building stock divided by decade of construction (graphs 4.4.3, 4.4.4), one can see that for both number of buildings and floor area, the high points are in the 1980s and after 2000. Around 19% of the buildings in Tampere, which make 23% of the total floor area, were built after 2000. Even 46% of the buildings in Tampere i.e. more than half of the total floor area, are no older than the 1980s. Considering the building stock of Tampere as a building and construction material reserve, it might be worthwhile looking a bit more closely into buildings and their attributes from these years. The high points around the 1980s explain the average age of buildings around 40 years. The young building stock bears the potential of staying in use for a longer time, i.e. there is no obvious threat of demolition due to high building ages. Same applies to the construction materials, even if those buildings need to be removed, there is a good change that their materials are not yet worn down and they could potentially be reused.

Past demolition has shown that especially buildings from the 1960s until the 1980s were demolished. More than 8 500 000 sqm, i.e. more than 45% of the total gross floor area of the building stock were built in those decades. Even though past demolition trends are not necessarily an indicator for the future, it is worthwhile looking more closely into which buildings were demolished during that time and how that might affect the stock.



Graph 4.4.3: Building stock numbers of buildings by decade of construction



Graph 4.4.4: Building stock gross floor area of buildings by decade of construction

Going into a bit more detail for each of the building type groups, graphs 4.4.5 and 4.4.9 show that the numerical superiority of detached houses and utility buildings is again an outstanding phenomenon. The numbers of both building types exceed any other building type throughout the construction decades. That comes with relatively little surprise, since detached houses have a long tradition in Finnish housing and utility buildings such as saunas, storages and other sheds usually come with them and other, mainly residential buildings. While the origin of the stock of detached houses mark their highest points in the 1980s and another one after 2000, the drop in construction in the 1990s can be well explained by the economic crisis that hit Finland in the beginning of that decade. The second most pronounced building type is row houses with a high point in the 1980s that stand for the construction decade of around one third of all existing row houses.

Against the overall trend, a fairly large number of blocks of flats was built in the 1960s and 1970s, the 1980s mark a minor low point which is followed by the highest peak in 2000 and onwards (graph 4.4.7). The drop in the 1980s could be associated with the upcoming of row houses that seemed to have a higher popularity only during this very decade.

Most of the remaining building types follow the overall trend with peaks of construction in the 1980s and the 2000s.

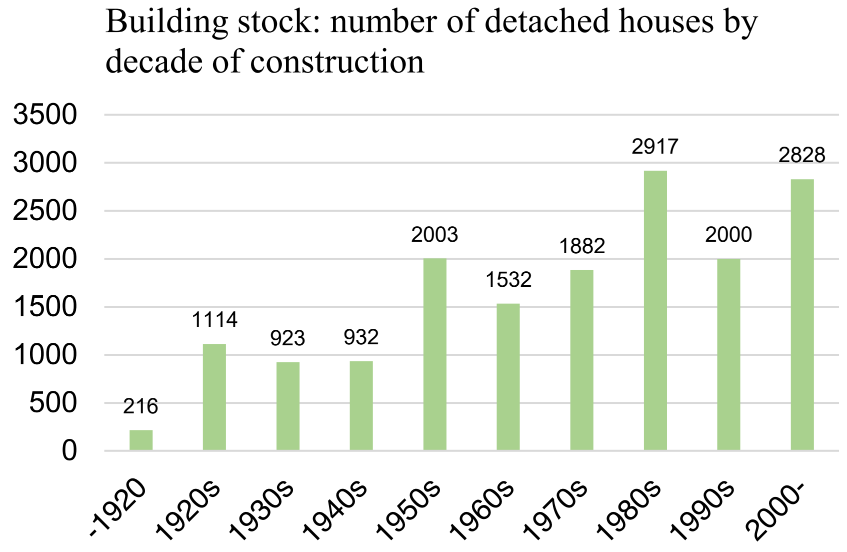
Divided by floor area, the most pronounced building type are blocks of flats (graph 4.4.8). In every decade, they accumulate to the largest amount of floor area with a peak in the 1970s and in the beginning of the second millennium. Detached houses (graph 4.4.6) show almost exactly the same trends as seen in the previous graph.

The overall findings as seen in graph 4.4.4 get more or less repeated throughout the building type groups which reflects the young age of Tampere's building stock.

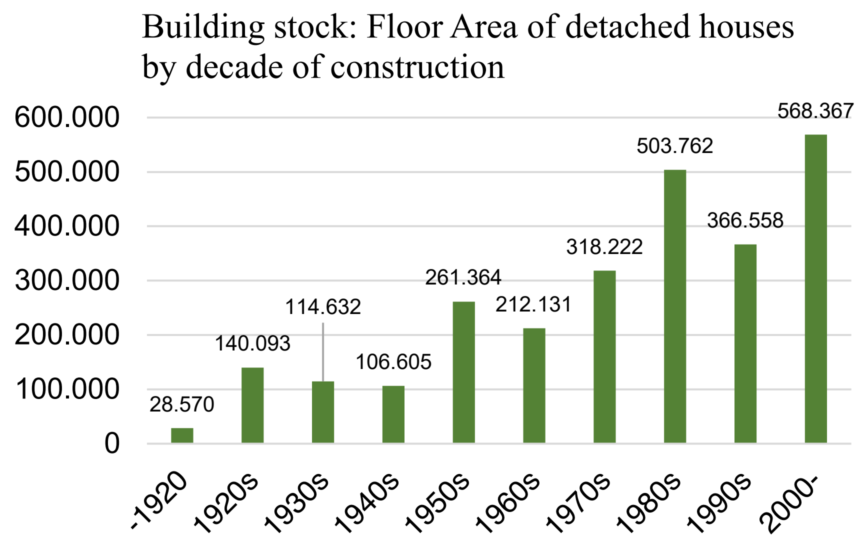
Based on past demolition, the stock of detached houses in Tampere may experience shrinkage especially for those older ones built between the 1920s and the 1950s. Overall, demolition of those buildings have been none of the major demolition patterns, nevertheless, demolition of old buildings also means to wipe out a bit of building culture that can never be replaced.

Especially commercial & office buildings from the 1960s and 1970s, i.e. almost 75 000 sqm of those buildings were demolished between 2000 and 2018. Buildings of that type from that decade have a chance to become target for demolition in the future. Same applies for public buildings during the same decades.

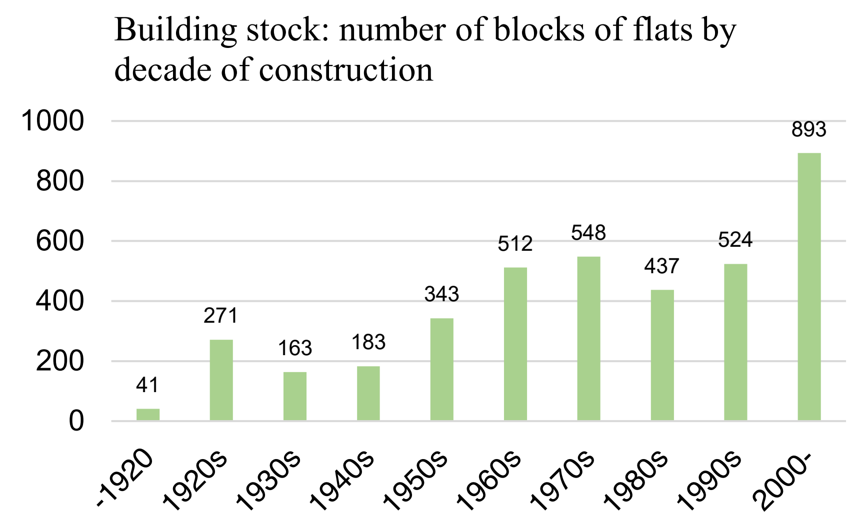
Most of the existing warehouses were built in the 1980s. The same decade has been in the focus of past demolition and considering the high demolition rate for those buildings, those buildings and their construction materials need to be considered in future protection measures. Most of the existing industrial buildings were built between the 1960s and the 1980s, while demolition had its peaks for buildings from the same decades. In other words, industrial buildings from between the 1960s and the 1980s might deserve special attention considering the potential of getting demolished.



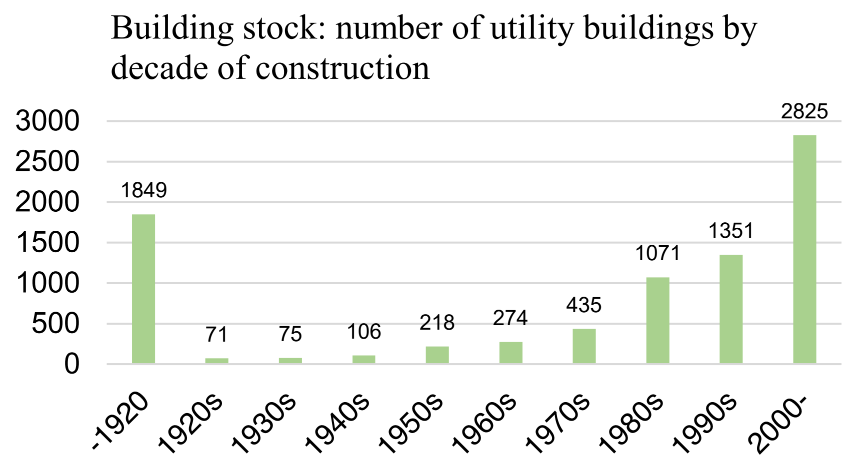
Graph 4.4.5: Building stock numbers of detached houses by decade of construction



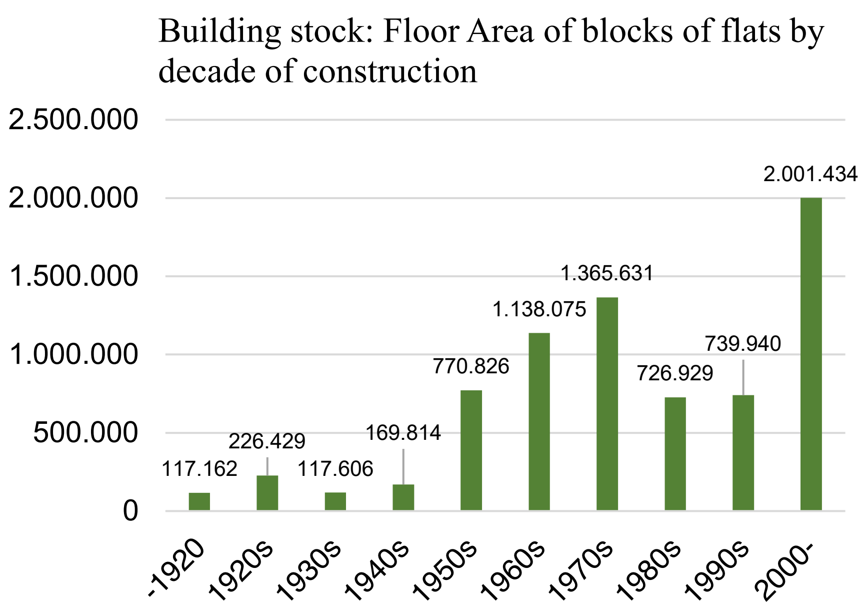
Graph 4.4.6: Building stock gross floor area of detached houses by decade of construction



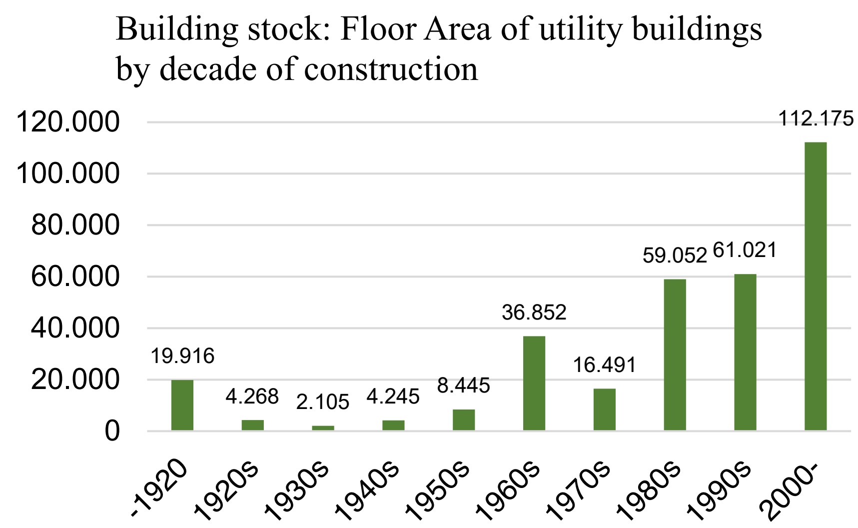
Graph 4.4.7: Building stock numbers of blocks of flats by decade of construction



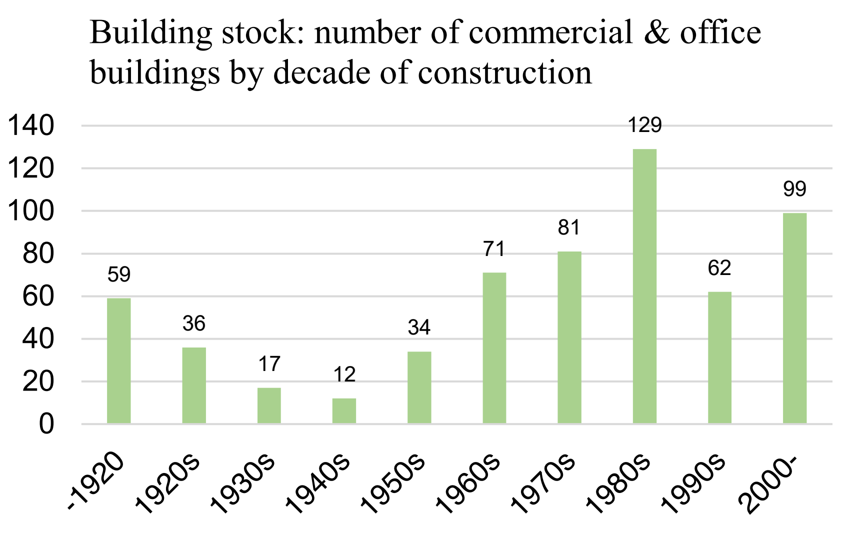
Graph 4.4.9: Building stock numbers of utility buildings by decade of construction



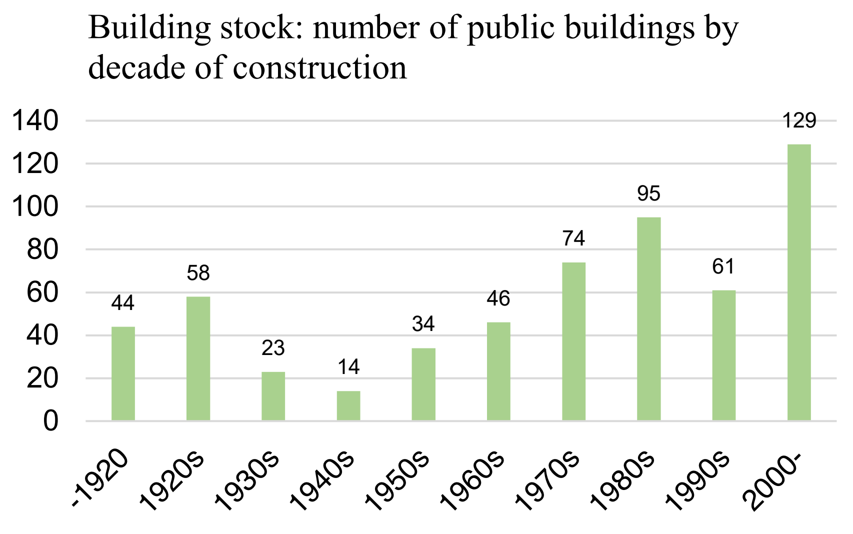
Graph 4.4.8: Building stock gross floor area of blocks of flats by decade of construction



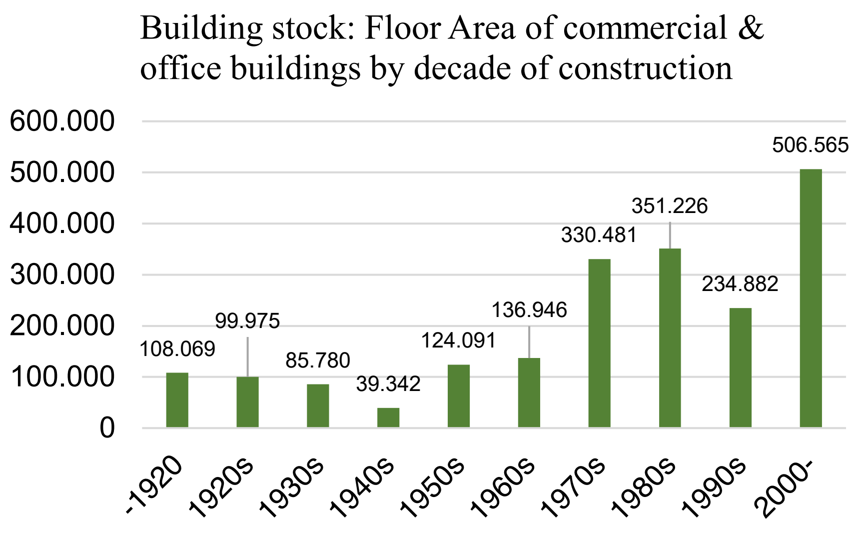
Graph 4.4.10: Building stock gross floor area of utility buildings by decade of construction



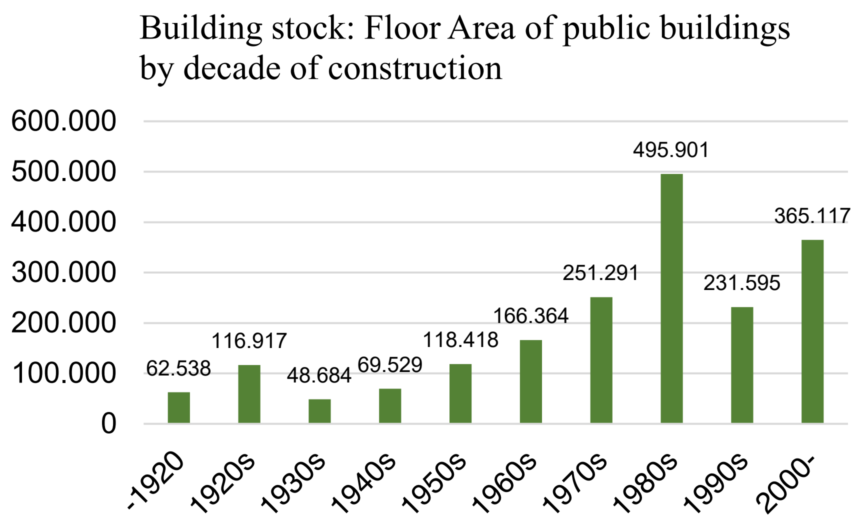
Graph 4.4.11: Building stock numbers of commercial & office buildings by decade of construction



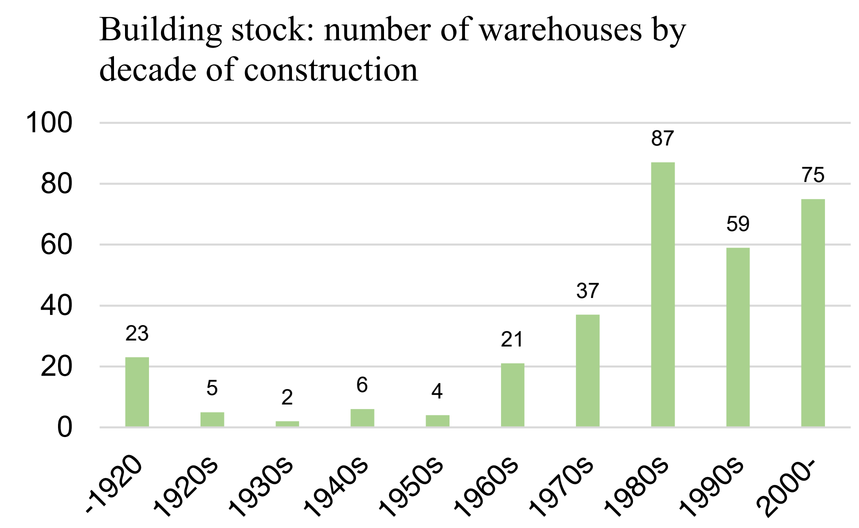
Graph 4.4.13: Building stock numbers of public buildings by decade of construction



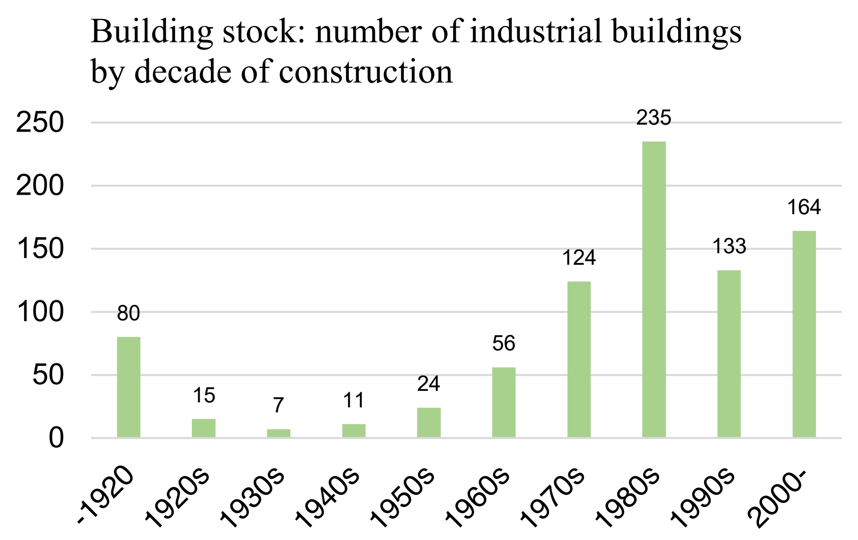
Graph 4.4.12: Building stock gross floor area of commercial & office buildings by decade of construction



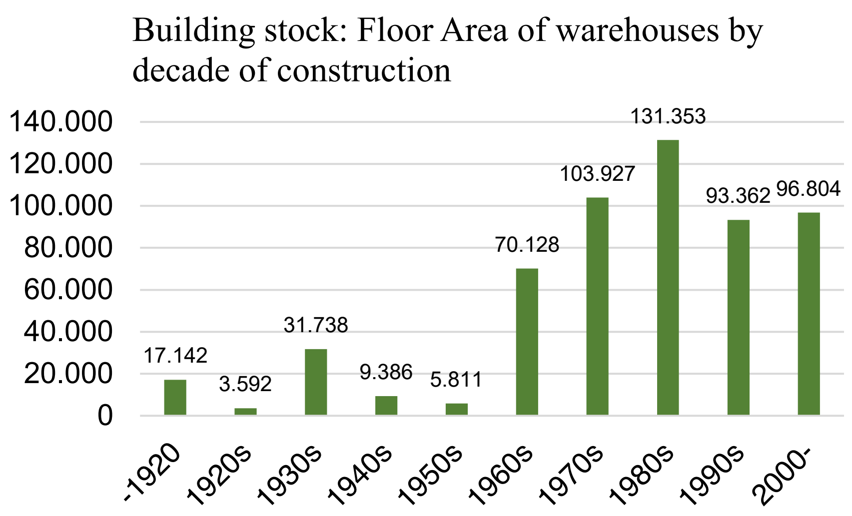
Graph 4.4.14: Building stock gross floor area of public buildings by decade of construction



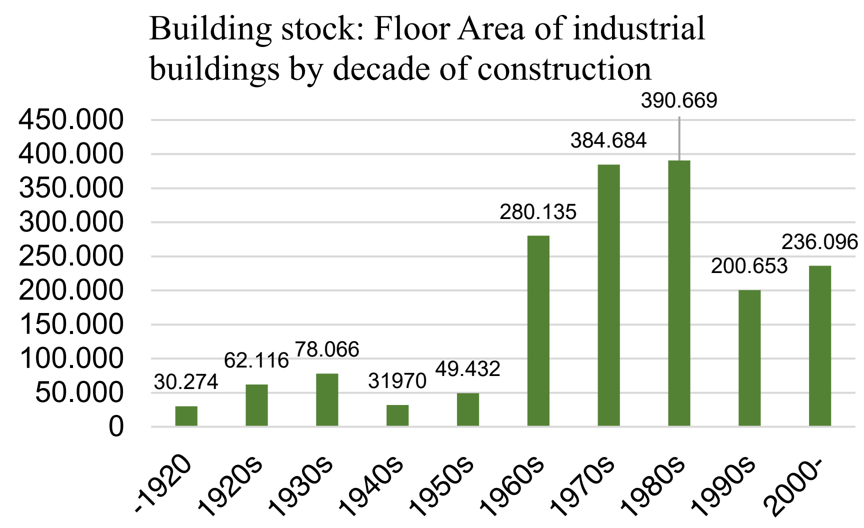
Graph 4.4.15: Building stock numbers of warehouses by decade of construction



Graph 4.4.17: Building stock numbers of industrial buildings by decade of construction



Graph 4.4.16: Building stock gross floor area of warehouses by decade of construction



Graph 4.4.18: Building stock gross floor area of industrial buildings by decade of construction

Material Composition

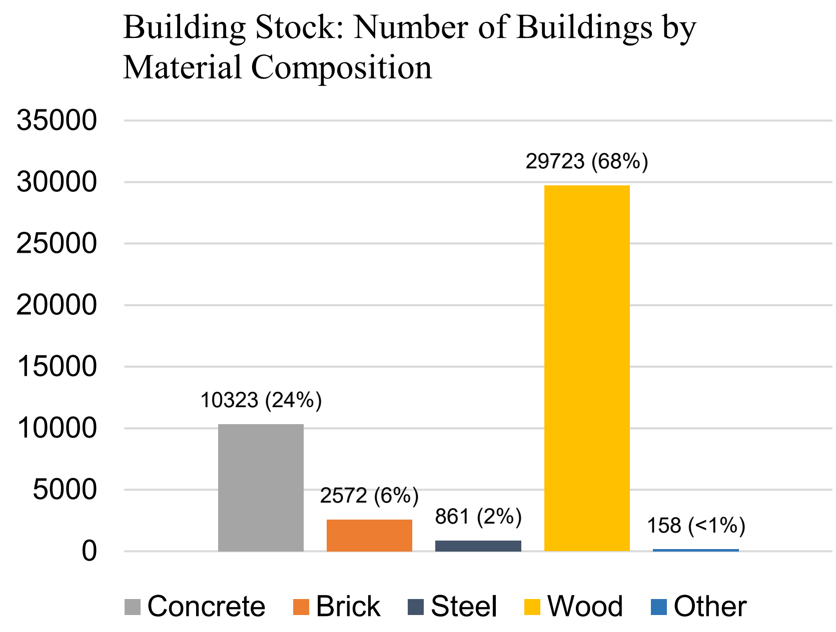
In total, for almost 75% of the buildings in Tampere which make around 98% of the total floor area, the analysed data contains reliable information regarding material composition of the stock. The following analysis is based on a material simulation where buildings that had no data of the building frame material were compensated with the relative number derived from each real building frame material (described in more detail in the method section).

For more than 68% of the buildings in Tampere, the main construction material is wood (graph 4.4.19). The second largest group mark concrete buildings. Around 6% of the buildings in Tampere are made of brick while steel buildings make only 2%. When looking at the material composition of buildings per floor area (graph 4.4.20), concrete buildings are much more pronounced. Almost two thirds of the built floor area in Tampere is made of concrete, 20% wood and almost 10% brick. Little below 5% is made of steel. The relative numbers vary quite significantly when looking at the floor area. Even though outnumbered, concrete buildings have a very high share of the total built floor area in Tampere.

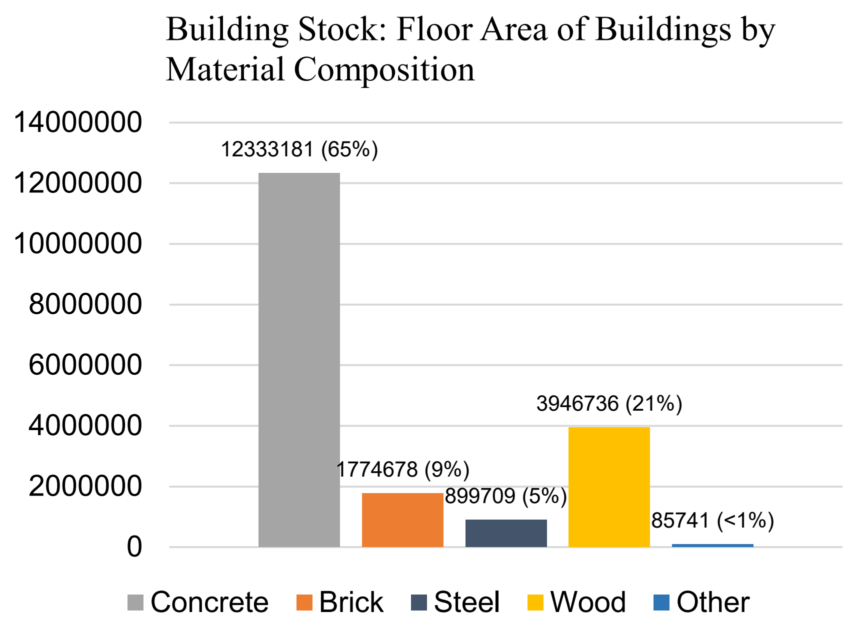
Being a rather energy and carbon intensive construction material, the extensive use of concrete can be seen quite critically. Especially for those buildings which are made of carbon intensive construction materials such as concrete, brick and steel (almost 80% of the total floor area), special strategies need to be developed in order to protect the value of those materials.

The rather large share of wooden buildings is a more positive finding as the natural construction material has a rather low value of embodied emissions.

From new construction and demolition, the material composition of the building stock is expected to shift even further towards concrete and steel buildings. Considering the high embodied emissions of those construction materials, Tampere needs to take actions towards a more responsible treatment of existing buildings and their materials.



Graph 4.4.19: Building stock material composition by numbers of buildings



Graph 4.4.20: Building stock material composition by numbers of buildings

Quite remarkably, 70% of blocks of flats are made of concrete, that makes 84% of those buildings' floor area (graphs 4.4.21 and 4.4.22). By their floor area, concrete blocks of flats are the single largest combination of building type and construction material. These buildings alone make more than 30% of total built floor area in Tampere.

The 40% of all public buildings that are made of concrete make more than 70% of its built floor area. Little over 45% of commercial and office buildings are made of concrete, these accumulate to three fourth of its total floor area.

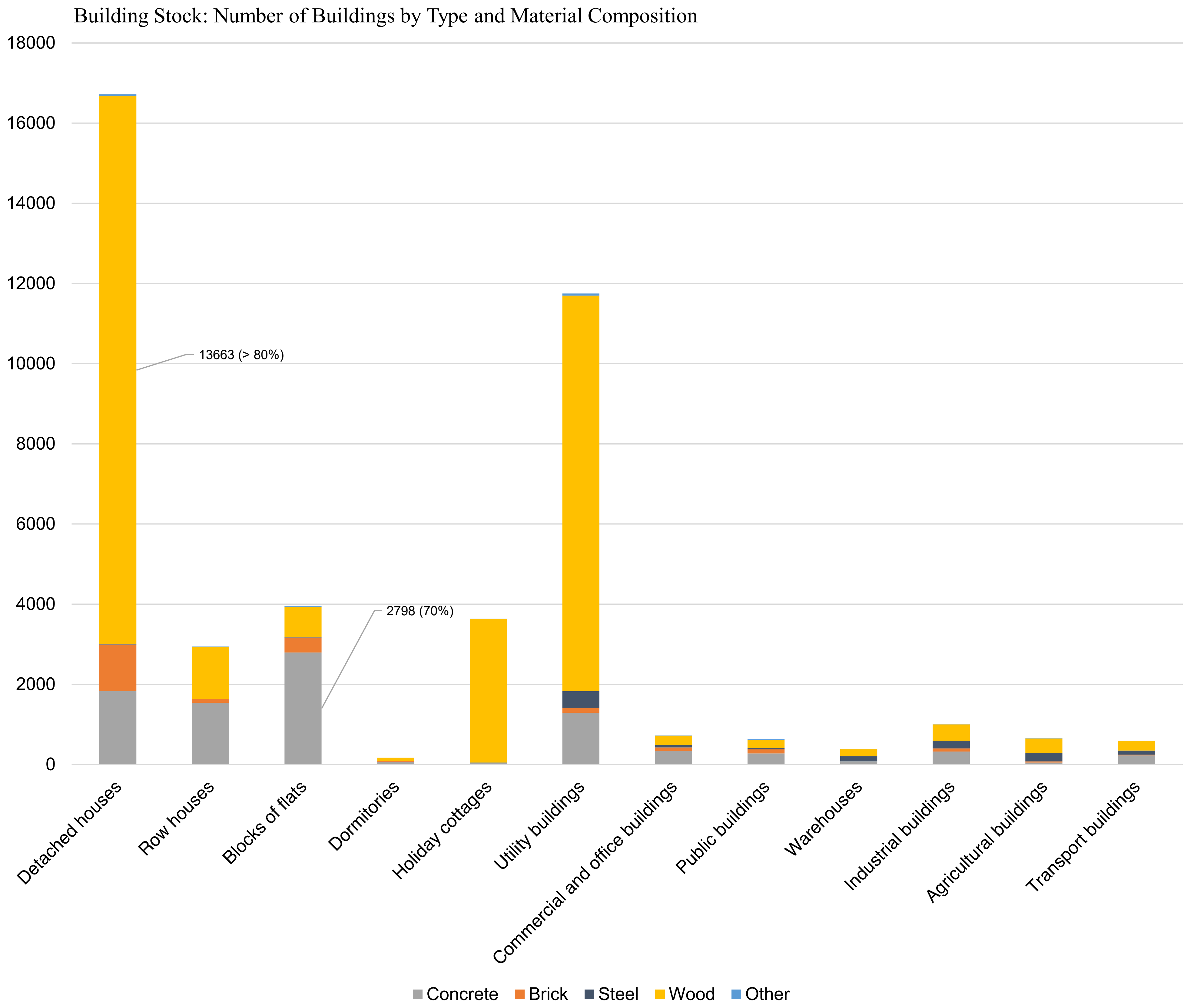
Overall, the previously found phenomena, concerning the high amount of concrete buildings, can be found again throughout the building types. While wood is mainly used in smaller buildings which appear in larger numbers (like detached houses and holiday cottages), concrete makes most of the floor area of almost any other building type group. While the negative effect of the production of concrete construction materials is eminent, the fact that it can be used for any building type would theoretically (very simplified as it leaves out technical a physical attributes of the several different components) imply a wide variety of different possibilities for reuse.

Even though, concrete is the predominant construction material, it seems that smaller buildings like detached houses, utility buildings and holiday cottages are rather made of wood while concrete is rather used for those larger buildings.

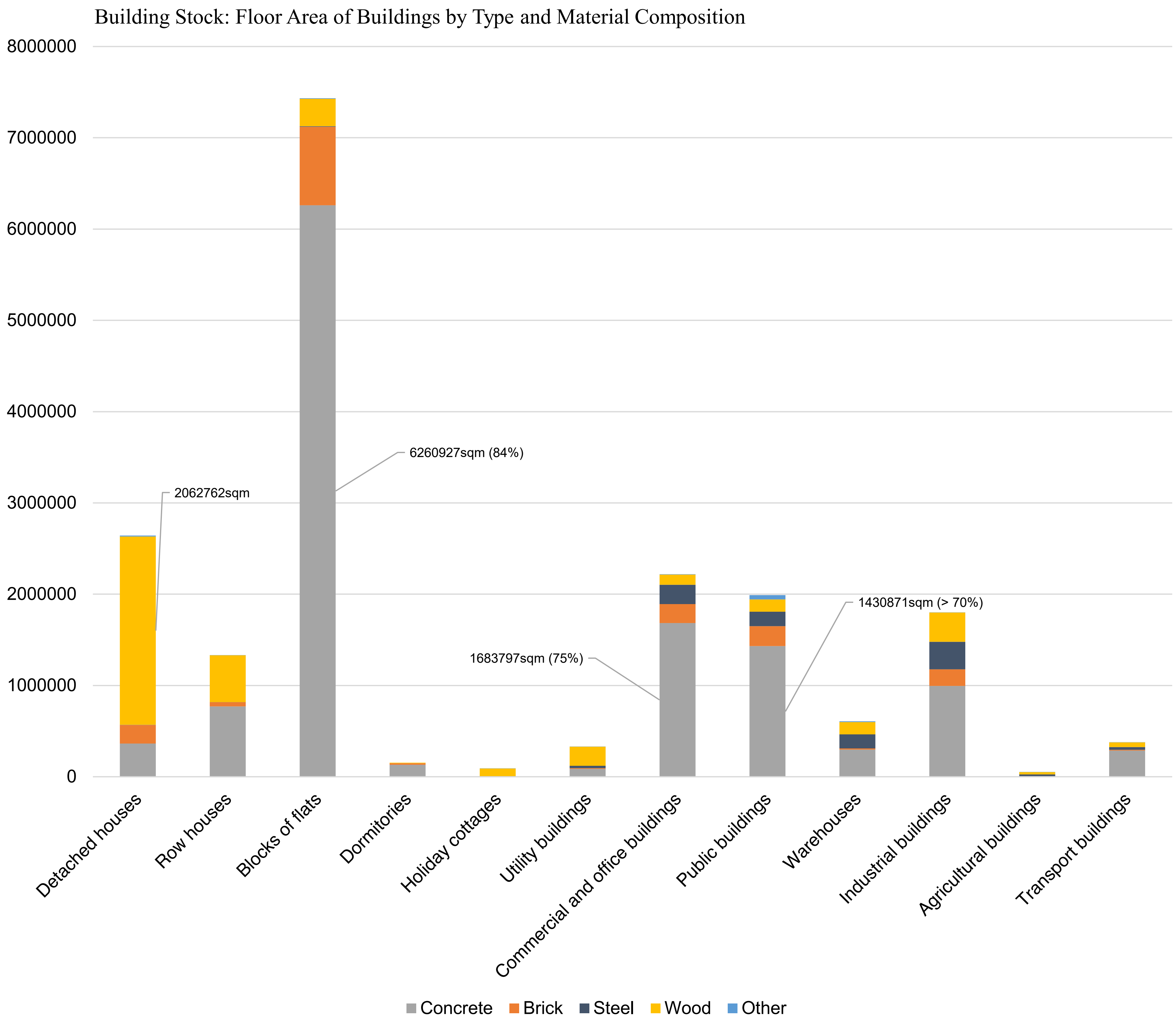
Considering the high replacement rates (low construction and high demolition), especially concrete warehouses can be expected to further vanish from the building stock while especially the size of blocks of flats made of concrete is expected to further increase.

While there is a not insignificant size of existing blocks of flats made of brick, those buildings have shown to rapidly decrease. With a replacement rate of more than 2 500%, demolition has exceeded new construction by far. Industrial buildings made of brick have shown to be demolished in a similar quantity. Considering the already rather low share in the stock and the historic value of those buildings in Tampere, continuation of this wasteful demolition behaviour can be seen rather critically.

One positive trend in Tampere's building stock development is the increase of wooden buildings. Excluding commercial & office buildings, the traditional Finnish construction material has increased for any other more significant building type group.



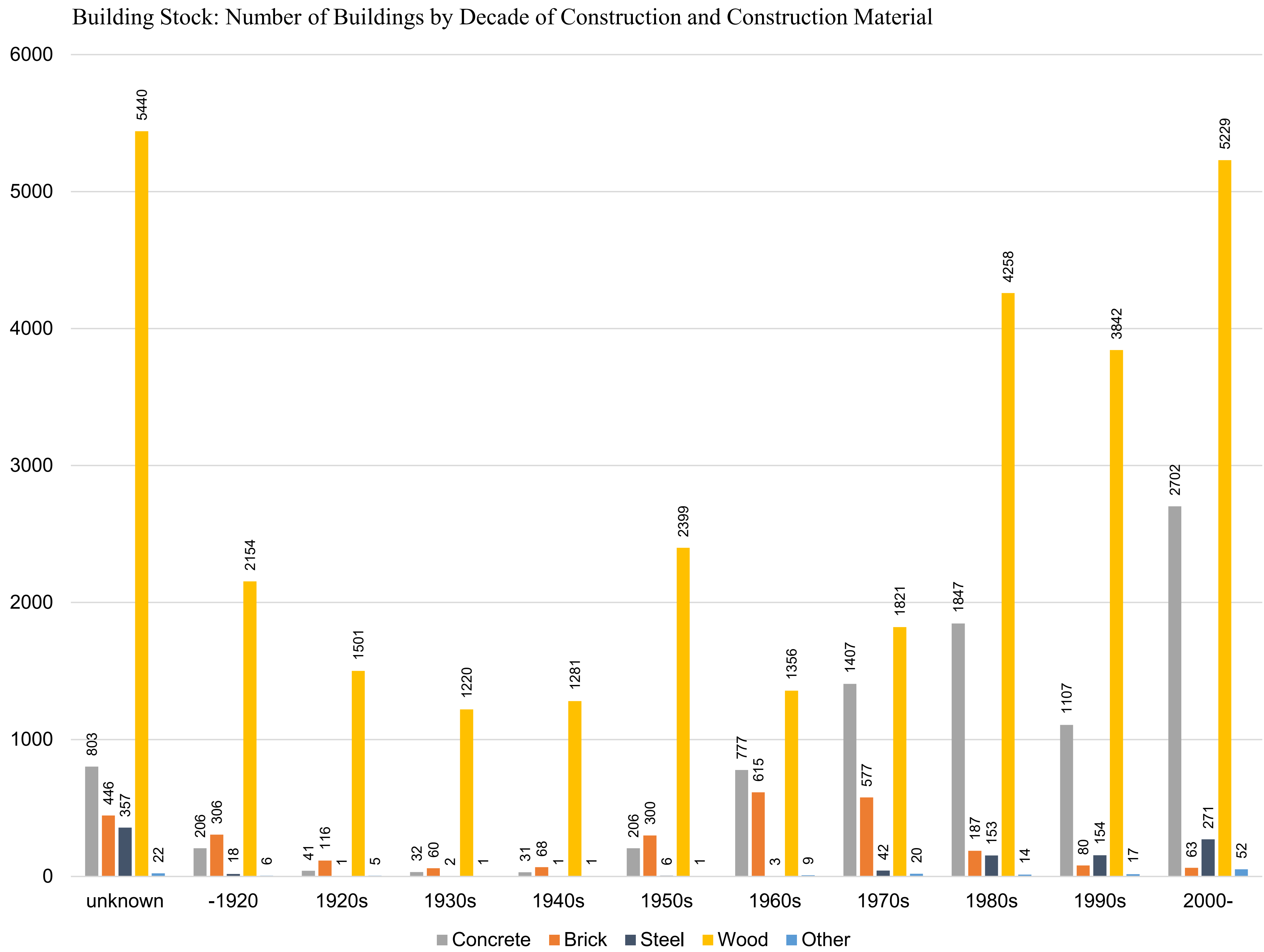
Graph 4.4.21: Building stock material composition by numbers of buildings and building types



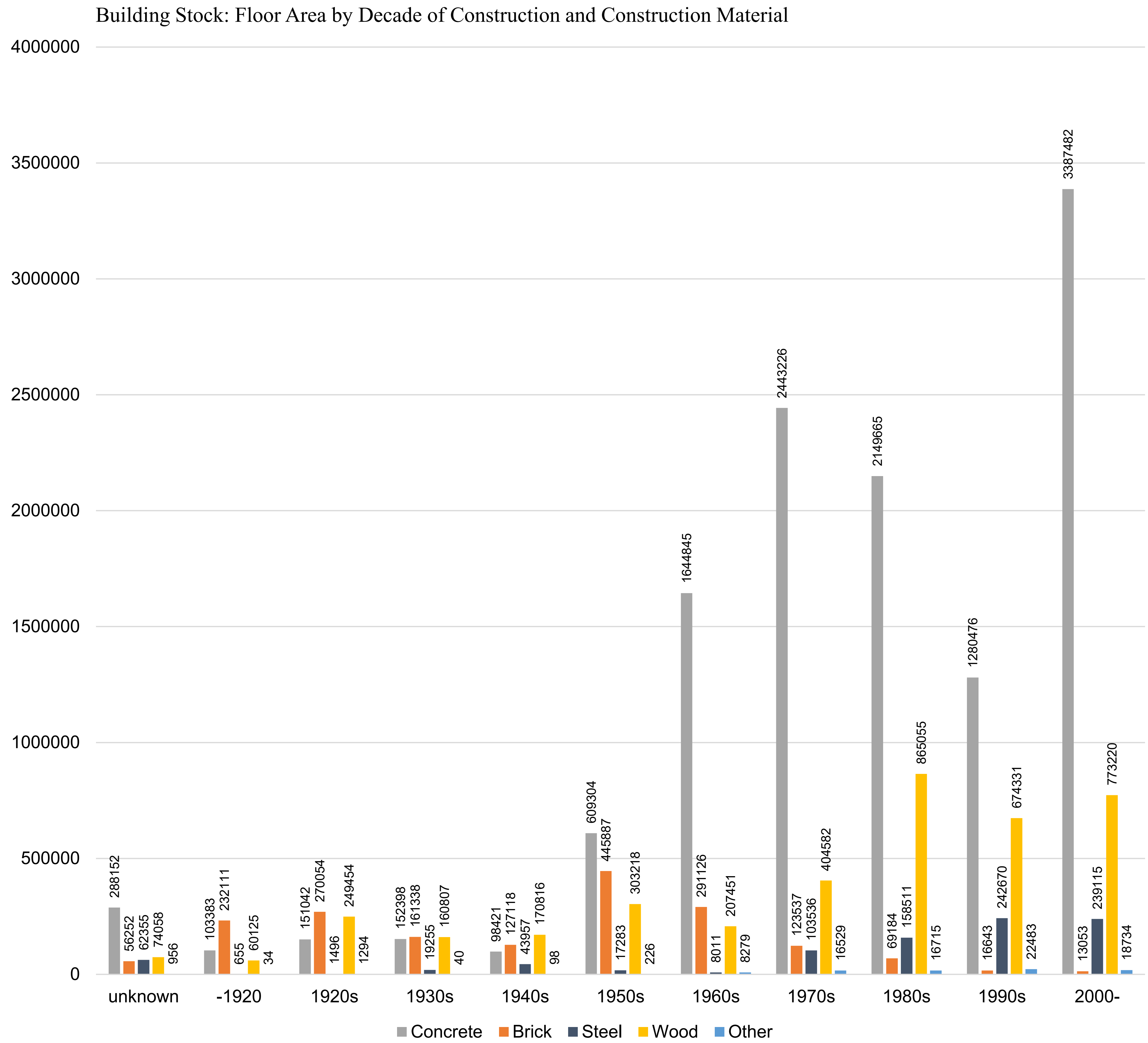
Graph 4.4.22: Building stock material composition by gross floor area and building types

Bearing in mind the highest average age, the existing stock of brick buildings shows large numbers of buildings from the 1960s and 1970s with another medium peak just before that in the 1950s. However, graph 4.4.23 shows also that with only 187 buildings from the 1980s it seems that brick buildings have lost their popularity for good. In fact, it seems that, while brick buildings become a less common building material, concrete has gained a massive construction boom. So, even though brick is said to be Tampere's traditional construction material, the high average age is also the result of hardly any new construction after the 1970s. Starting from the 1960s, there are more concrete buildings than brick buildings in any following decade while concrete buildings peak in the 1980s and even more pronounced in the 2000s. Steel buildings seem to steadily increase over time with noteworthy peaks starting in the 1980s. The amount of wooden buildings throughout the decades runs almost linearly until the 1980s. There is a noteworthy peak of 2 399 buildings in the 1950s that can be explained with the new construction of post-war residential buildings. With over 3 500 buildings annually starting from the 1980s, more than half of the existing wooden buildings were built since then.

The previously explained phenomena for concrete and brick buildings are even more pronounced when looking at the floor area (graph 4.4.24). Most of the existing brick building mass derives from the 1950s. Secondary peaks can be observed in the 1960s and also in the 1920s. Looking at the floor area, in every decade since the 1950s, concrete buildings exceed any other construction material, including wooden buildings, by far. Concrete was the most common building material in the 1970s while the 2000s are even more pronounced. But also, wood was used extensively in the 1980s and the 2000s. Steel is the least commonly used building material throughout the decades. Yet, it is worth mentioning that more than half of the existing gross floor area of steel buildings was made in the 1990s and 2000s.



Graph 4.4.23: Building stock main construction materials by numbers of buildings and decade of construction

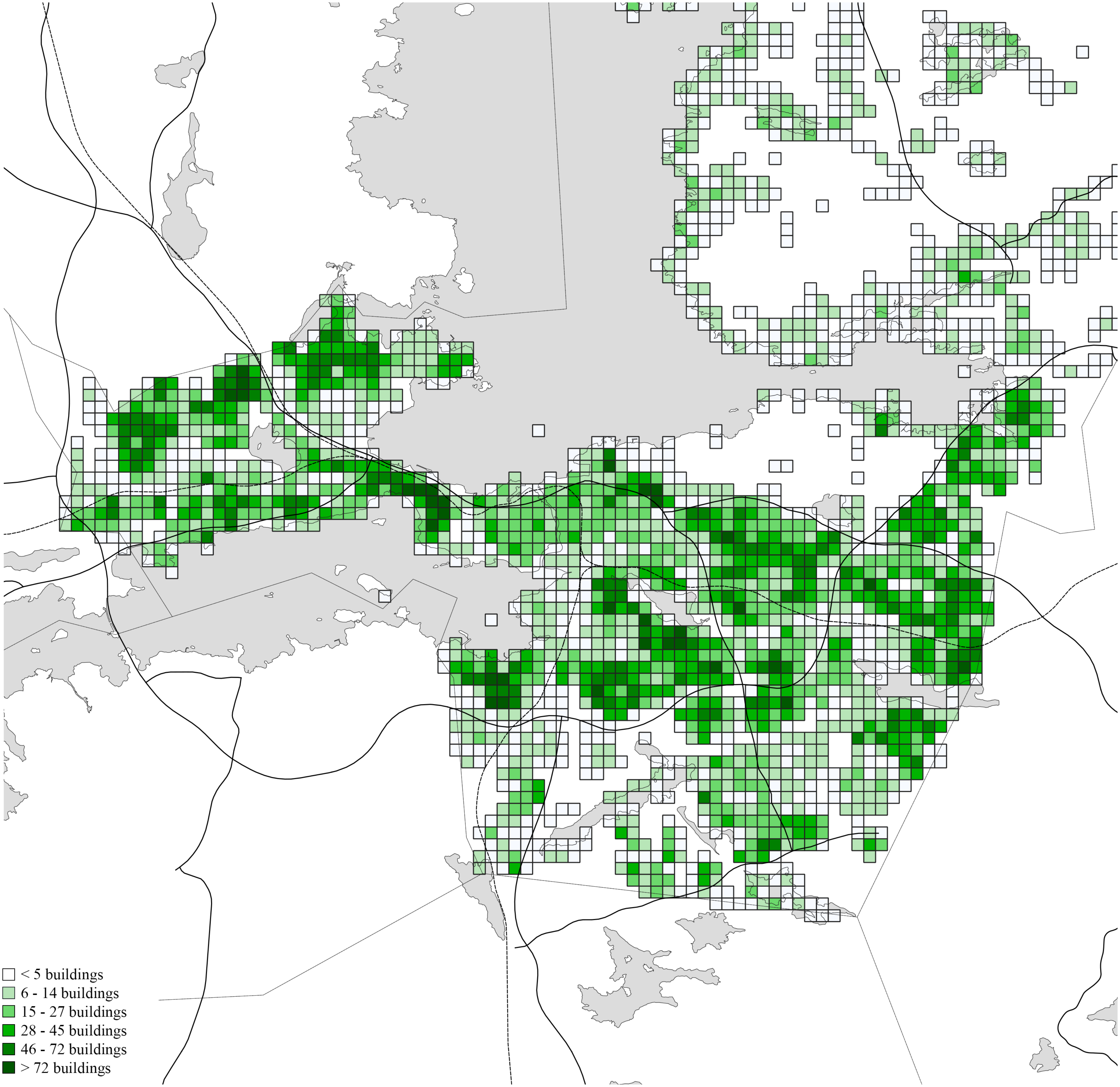


Graph 4.4.24: Building stock main construction materials by numbers of buildings and decade of construction

Spatial distribution

The second aspect of this study is the spatial distribution of buildings and built floor area in Tampere. In map 4.4.25, every square represents the amount of buildings that existed in 2018 inside of it, the darker the colour, the more buildings. One can see clearly that there are clusters surrounding the city's centre. These dark areas are mainly detached housing areas or allotment gardens with a medium high density. The city centre has a brighter green colour which indicates a rather average number of buildings.

One of the darkest spots in the west is the well-known area of Pispala and Tahmela. On this ridge between the two lakes Näsijärvi (North) and Pyhäjärvi (South) one can mainly find detached and semi-detached houses which used to be homes of workers' families. Clusters of large numbers of buildings can also be found in the areas of Nekala or Kauppi allotment gardens.



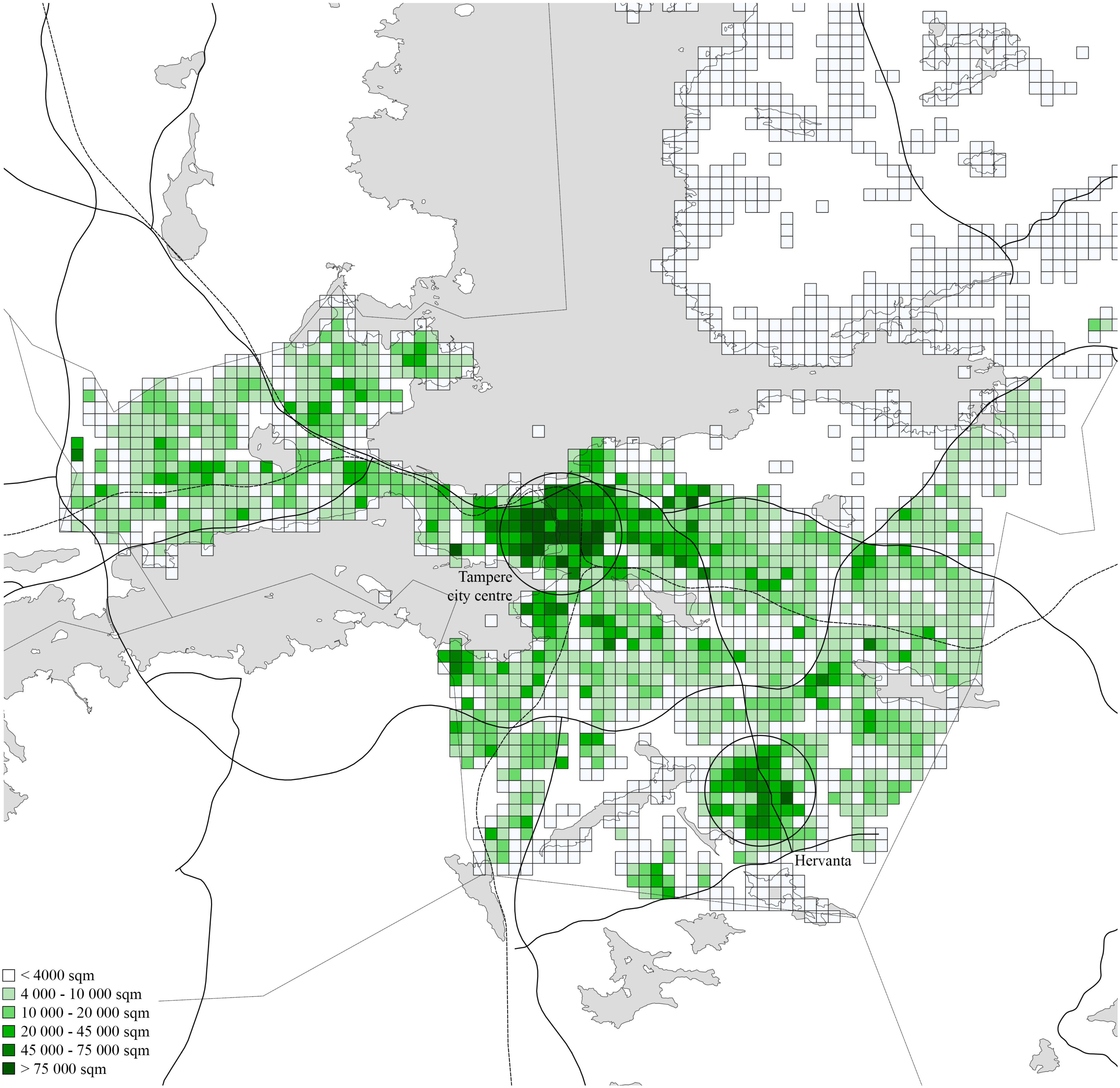
Tampere construction 2000 - 2018

scale | 1:85 000

Map 4.4.25: Grid of total number of buildings of stock

Map 4.4.26 shows the spatial distribution of the existing stock in the city. While in the previous figure, every square gave information on the amount of buildings it contained, this one shows the total amount of built floor area. On this map, two distinct areas can be identified. The first one is the city centre, as seen in the middle of the map. Here, one can find a large variety of compact building typologies. The trademark of the city centre is its 19th century grid-like street plan in which the buildings lie. The oldest buildings, often made of the typical brick material, date back to the 1880s but many old, especially wooden housing has been replaced during the 20th century. However, diving into the city to human eye level, one of Tampere's distinct features are the remaining brick, often former industrially used, structures that, in many cases serve a new purpose than intended during their construction.

The second area, towards the south-east, is the satellite town Hervanta. In the 1970s, the city decided to establish the university campus in this area and over the years, the area has developed into a more or less independent neighborhood, mainly comprising of mass housing in prefabricated concrete and public buildings in the centre.



Tampere construction 2000 - 2018

scale | 1:85 000

Map 4.4.26: Grid of total gross floor area of buildings of stock

Demolition potential

Based on the findings from demolition, new construction and demolition an analysis of the existing building stock was conducted in order to spatially identify those buildings which appear to be especially endangered. For this purpose, the most heavily demolished building types (warehouses, industrial buildings, commercial & office buildings and public buildings) were selected and located and divided by the decades of construction from which most of those buildings were demolished.

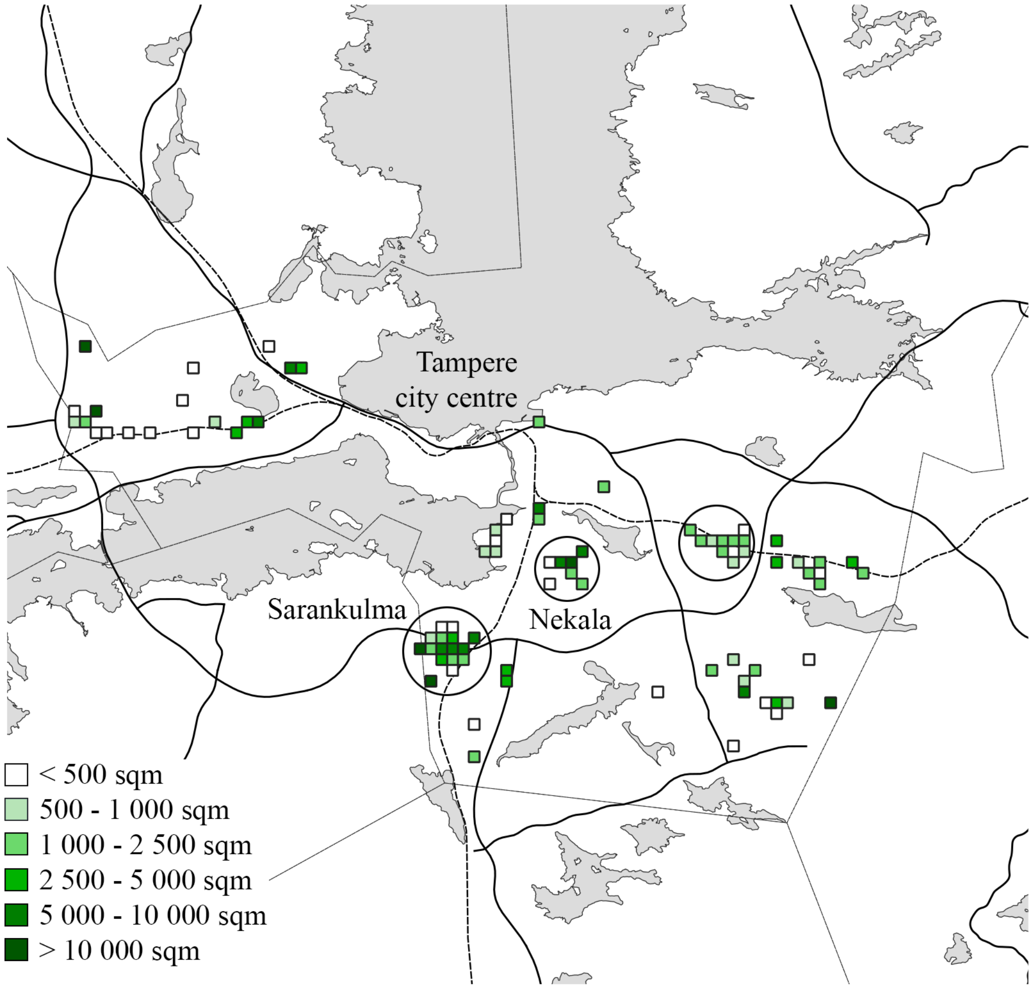
Large numbers of warehouses from the 1970s and 1980s were demolished between 2000 and 2018. Map 4.4.27 top left corner shows the areas in Tampere in which those building types exist in 2018. One can see that most of the buildings are located close to traffic junctions.

Most of the industrial buildings which were demolished after 2000, were built between the 1960s and the 1980s. Map 4.4.27 top right corner shows the areas in Tampere in which those building types gather and, much like warehouses, most of the buildings are located close to traffic junctions.

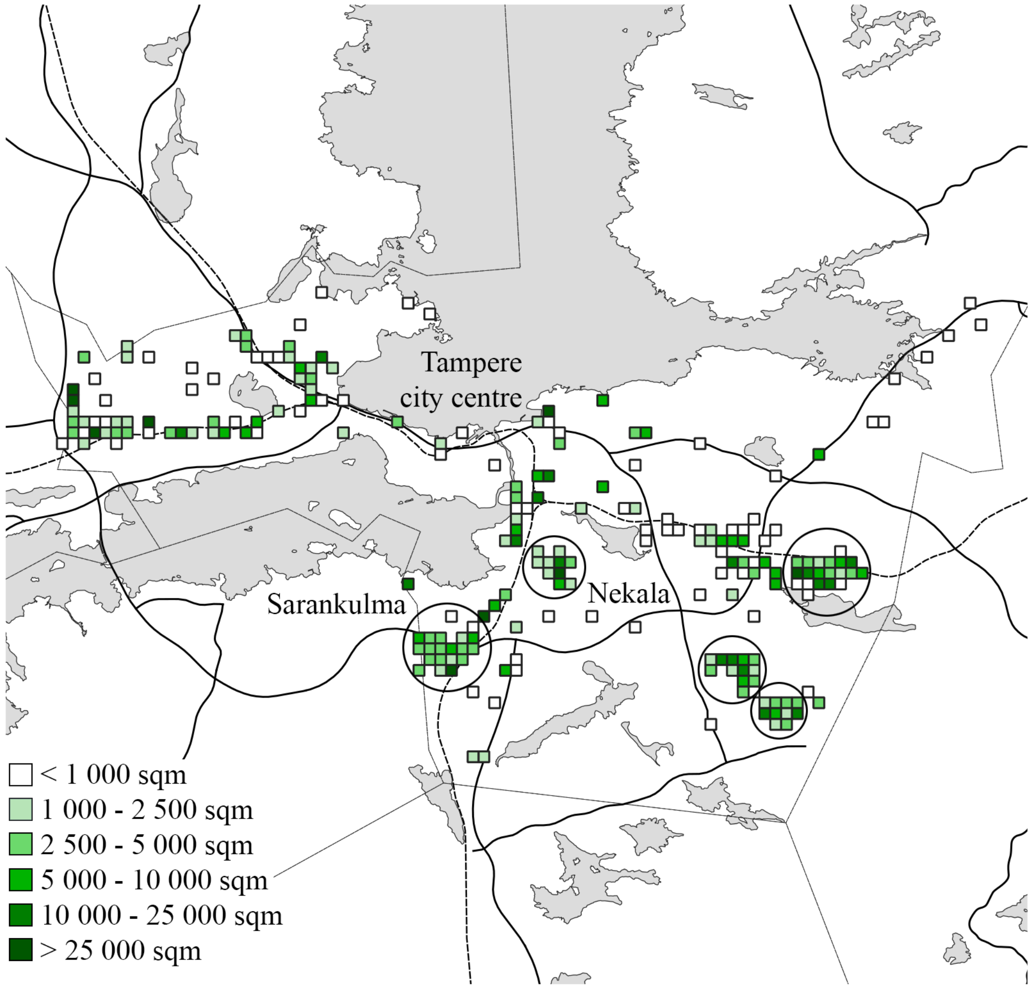
Interestingly, though little surprising, industrial buildings and warehouses are often located in the same area. Especially two areas overlap: Sarankulma and Nekala, both situated in the South of Tampere. This study is no future prediction. It is possible that buildings in those areas will not get demolished very soon. However, it might be worthwhile looking more closely into those areas and see, based on factors like building condition, vacancy, etc., whether there is a chance that those buildings are threatened to be demolished.

The study has shown that public buildings, especially from the 1960s and 1970s were target of demolition work between 2000 and 2018. Map 4.4.27 lower left corner shows where public buildings from the 1960s and 1970s are currently located. It is little surprising to find those building types rather scattered around the city. However, there is a semi-cluster in the east of Tampere around the Kauppi hospital district. It seems that for public buildings it might be worthwhile to jump into the building level as the study of any urban patterns has its limitations.

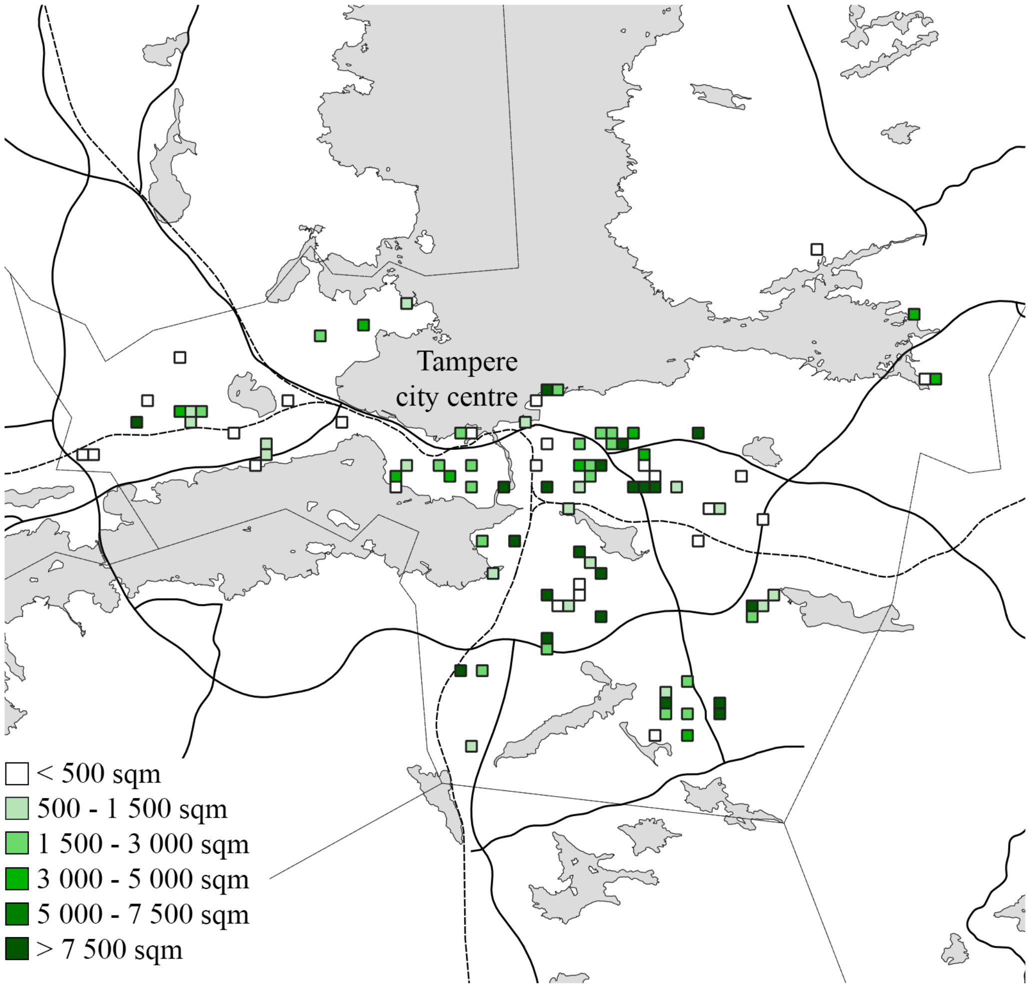
Between 2000 and 2018, especially commercial & office buildings from the 1960s and the 1970s were target of heavy demolition work. Map 4.4.27 lower right corner shows the areas in which those buildings are located in 2018. Most of those buildings area clustered in the urban centre of Tampere. It would be worthwhile looking for those buildings more closely, especially whether they fit today‘s spatial requirements. Since the average size of commercial & office buildings has drastically increased over the years, especially smaller buildings around 1 400 sqm might become target of demolition in the city centre.



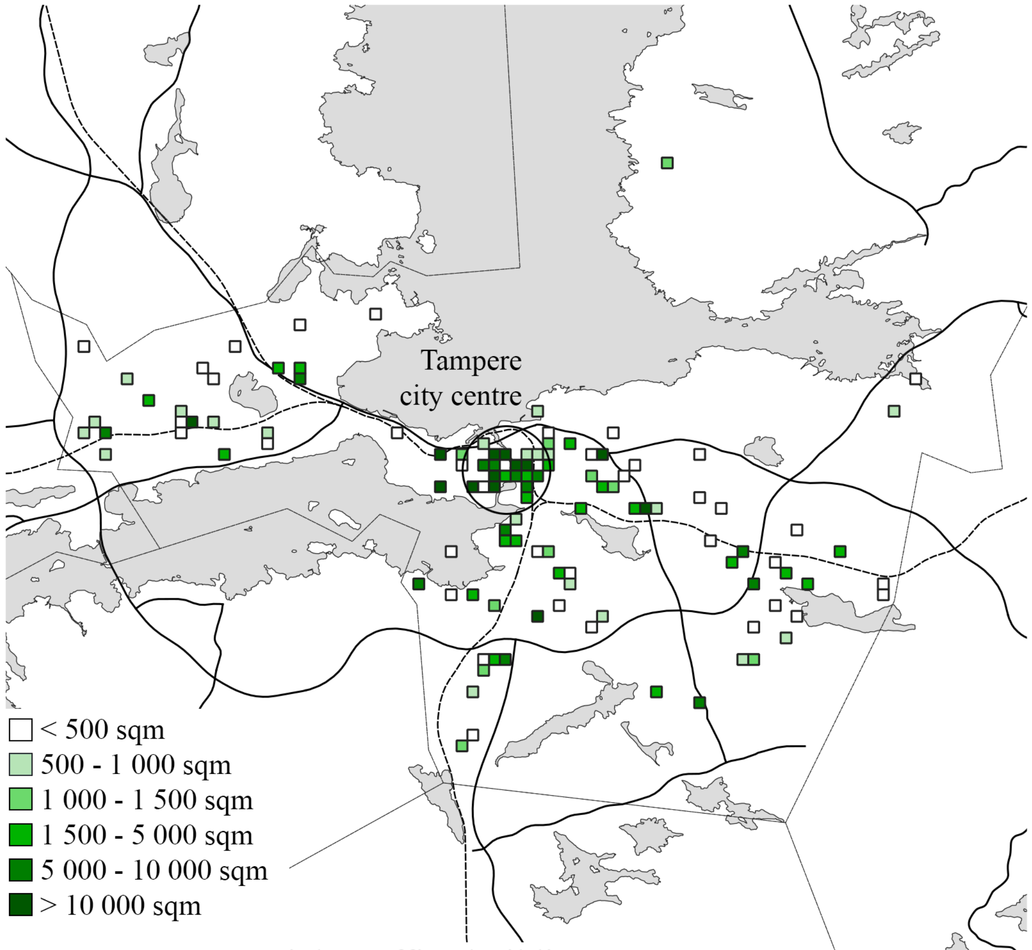
Tampere warehouses built 1970s - 1980s scale | 1:175 000



Tampere industrial buildings built 1960s - 1980s scale | 1:175 000



Tampere public buildings built 1960s - 1970s scale | 1:175 000



Tampere commercial & office buildings built 1960s - 1970s scale | 1:175 000

Map 4.4.27: Map clusters for endangered building types

In the lower right corner of map 4.4.27, the urban centre of Tampere was found to be a hotspot of possibly endangered commercially used buildings. Map 4.4.28 shows a zoom in of just this area and a more detailed overview of the location of those buildings. The buildings that are highlighted on this map are mainly stores below 3 000 sqm built in the 1960s and 1970s.

The map is the result of a systematic analysis of buildings that, based on previous demolition patterns, appear to be endangered. It is therefore no future prediction. It can be said though, that one of these buildings is already planned to get demolished in 2020 or 2021 and the frequent change of tenants of another example shows that location and/ or spatial and/ or functional properties of that building are inadequate.

This exemplary study shows how the findings from this study could potentially be used to identify endangered buildings and urban areas. This method could become a meaningful tool for urban planners in order to develop strategies for those buildings to protect them and their material values from demolition.

Tampere centre ▭ existing buildings ■ existing commerical & office buildings built 1960s - 1970s below 5 117 sqm scale | 1:8 000

Map 4.4.28: Possible future demolition city center

5

DISCUSSION

Blocks of flats do not only make the largest share (39%) of the existing floor area (stock), they were also the most frequently built building type between 2000 and 2018 (45% of built floor area). With more than 75% of newly built floor area and 65% of the stock, the share of concrete, as construction material, is constantly increasing. Combining these facts with the material's energy and carbon intensity (around 0,073 – 0,159 kg CO2 per kg concrete based on the ICE embodied energy and carbon footprint database (2006)), it would be wise to take measures towards sustainable strategies how to deal with the continuously increasing share of concrete buildings, especially blocks of flats which make 30% of total floor area. On the other hand, the large numbers of concrete blocks of flats is an opportunity for circular economy strategies. Since many of these buildings are built with similar construction techniques, i.e. precast concrete elements, these elements could potentially be reused for the construction of other blocks of flats.

While the average age of 50 years for demolished buildings is roughly in line with the Finland-wide average, the building types that make 77% of demolished floor area (commercial & office, public, industrial, agricultural buildings and warehouses) get demolished after only 37 years. In other words, more than three quarters of demolished floor space and its materials are lost (or downcycled) after only 37 years. On top of that, concrete makes 32% of total demolished floor area and especially warehouses, industrial buildings and public buildings have a massive share of that. With only 36 years, the average age of concrete buildings is much below the overall average. Again, pointing out concrete buildings, their short lifespan and their steadily increasing amount, it is crucial to develop strategies in order to avoid these highly wasteful demolition patterns.

With 53 years, brick buildings are the oldest construction material in Tampere. Being known for its industrial buildings made of the red clay bricks, one of the reasons for the high average age is the increasing popularity of the much easier-to-handle building material concrete. The result is 18% of demolished floor area being made of brick, hardly any new construction in the recent past years (< 1% between 2000 and 2018) and being listed as heritage, very old brick buildings are often protected from demolition. With an average value of 0,24 kg CO2 per kg, the red bricks are relatively carbon intensive, therefore the shrinking popularity throughout all building types (except for detached houses) has also a positive side effect of less dependency on a carbon intensive construction material. Nevertheless, it is the iconic construction material in Tampere and the drastic reduction of its usage might have a negative impact its identity.

Existing (22 years) and demolished (23 years) steel buildings are by far the youngest construction material. Even though it is a relatively young material in the Finnish construction industry, it must be handled with extra care as it is also very energy and carbon intensive (1,37 kg CO2 per kg steel). The standardization of steel elements on the other hand, bears a great potential to reuse them in whole. Even though recycled steel can be of high quality, the recycling process consumes a lot of energy.

Demolished blocks of flats and commercial buildings are of rather similar construction techniques and materials. However, the former has reached an average age of 65 years while the latter was demolished after and average of 36 years. Looking at this large difference of 19 years, it becomes evident that the main construction technique or material are not the main driver for demolition.

Wooden buildings make 20% of the total stock floor area. With 72 years, existing wooden blocks of flats are among the oldest buildings in Tampere. However, only 17% of newly built floor area is made of wood, while these buildings make 26% of total demolished floor area. Even though wood – if properly used – has the potential of being a sustainable construction material, it seems that its popularity is still relative compared to concrete. On the other hand, the new construction with wood exceeded demolition for almost all building types, except commercial and office buildings, warehouses, agricultural and transport buildings.

In general, the replacement rates for residential buildings, being much smaller than for non-residential buildings, suggests a large increase in housing, especially for blocks of flats, with very low demolition and high new construction (2% replacement rate). The same phenomena can be observed when looking at the replacement rates for row houses (4%) and detached houses (8%), which show the sharp increase in single family units. These stand in contrast with high replacement rates of agricultural buildings (348%) and warehouses (192%) which are going through a significant decline. Agricultural buildings might lose popularity since, due to higher efficiency, less buildings are required and because the urban area of Tampere is expanding, hence farmland is getting occupied. The decrease of warehouses and almost stagnation of industrial buildings (replacement rate of 90%) in addition to the low replacement rate of commercial & office buildings (30%), indicates a shift from "traditional" heavy industries towards a more service-based economy. All in all, it seems that one of the key drivers for demolition in Tampere, is a shifting demand for building types, away from industrial buildings, warehouses and commercial & office buildings towards housing, especially in blocks of flats and larger commercial & office buildings.

Of approx. 1 000 000 sqm demolished floor area, industrial buildings (20%), warehouses (> 16%), commercial & office buildings (14%), utility buildings (11%) and public buildings (11%) take each a rather even share. Compared to new construction (45% blocks of flats, 13% detached houses, 11% commercial & office buildings, etc.), demolition seems to be a more diverse phenomenon than new construction.

Comparing the average sizes except for row houses and utility buildings, newly constructed buildings are bigger than demolished ones. It seems that one driver for demolition in Tampere has been the need for larger buildings. This phenomenon is especially pronounced for newly built blocks of flats which are on average 3,64 times larger than demolished ones. Also, new commercial & office buildings are 3,63 times larger than demolished ones, which adds to the theory of a shift towards a service-based economy. With the average size of newly built public buildings being two times as big as demolished ones, Tampere is becoming a more and more densified urban area. An increased amount of people therefore, results in an increased demand for public functions. The other side of the medal are detached houses, which also show a twofold in size from demolition to new construction. Combined with the shrinkage of Finnish households, the increase in property sizes result in a high increase of material and energy use per capita.

The areas in Tampere, which are dominated by new construction, are most of greenfield developments at the edges of the city (e.g. Vuores, Lintuhytti, Muotiala, Korkinmäki) and in some cases, densification areas of an already existing urban fabric (e.g. city center, Hervanta, Tampella). In total, greenfield areas accumulate to more than 2 000 000 sqm, i.e. 46% of new construction, while permanent residential buildings almost make three quarters of that built floor area. In the quantitative study, the densification of Tampere was identified as one of the urban phenomena in the city and the spatial study clearly supports that finding.

The areas that are dominated by demolition are usually brown- and greyfields of which some are waiting to be turned into residential and mixed residential-commercial districts (e.g. Onkiniemi) while in other cases, infrastructure developments were the driver (e.g. Iidesranta). Most often, the phenomena are too diverse to identify any obvious pattern. These areas make almost 125 000 sqm, i.e. 12% of total demolished floor area. As with whole demolition in Tampere, most of these buildings are industrial buildings (32%) and warehouses (23%) but also commercial & office (20%), transport (14%) and public buildings (12%) can be found in these clusters.

In areas where land use change is the cause for demolition, over 250 000 sqm, i.e. almost 25% of total demolished floor area are located and almost 800 000 sqm, i.e. around 18% of total new construction. Usually, warehouses (30%), industrial buildings (> 25%), commercial & office (> 20%) and public buildings (10%) were replaced mostly by blocks of flats (60%) and larger commercial premises (24%) or public buildings (11%). These replacement areas reflect the overall trends found in the quantitative study: 1. Construction of blocks of flats is the driver for demolition of industrial buildings, warehouses and commercial & office buildings and 2. larger buildings, especially blocks of flats and commercial & office buildings replace smaller buildings.

6

CATALOGUE OF MEASURES

The potential for reusing existing construction materials has its limits. As found out in the study, demolition waste would theoretically cover up to one fourth of newly built floor area in Tampere, which means that utilizing the potential of demolition waste doesn't resolve the overall material issue. Nevertheless, the arguments against demolition are predominant and – based on the principles of a circular economy – there is a series of practices that can be adopted by urban planners and architects in Tampere, in order to achieve a more sustainable built environment which might even influence further cities to change current construction and demolition practice. The following measures are largely reduced to aspects found by the study at hand and therefore, are not yet a comprehensive image of the whole need for transformation in economy and society. The following paragraph is structured from the urban scale to the building scale, while in each of them management of existing stock is followed by strategies for future new construction.

6.1 Urban Scale

6.1.1 Studying the Urban Mine

In order to get a better image of the urban mine, Tampere urgently needs to initiate further research on its urban material flows. While this study has given a good basic overview, further discoveries of patterns in the stock, construction, demolition and replacement will help to quantify and develop more detailed strategies to adapt buildings or to facilitate reuse of used construction materials. To allow better research, Tampere needs to collect and provide reliable data with high quality standards, especially for demolition and motivations behind it. Perhaps, before a building gets demolished, those who make the final call will have to provide information on which grounds demolition was chosen to be the best solution. During this research, errors in the data have created several obstacles that overcomplicated conducting the study while a smooth process would have helped to go into more detailed aspects. Especially, reliability of data about the material composition for non-residential buildings was found out to be relatively low which needs to be improved in order to utilize the city's urban mining potential. For example, material composition indicators (MICs) should be created for representative building types. By extrapolating those based on the quantitative stock and flow analysis, studies will provide more accurate information on the material quantity.

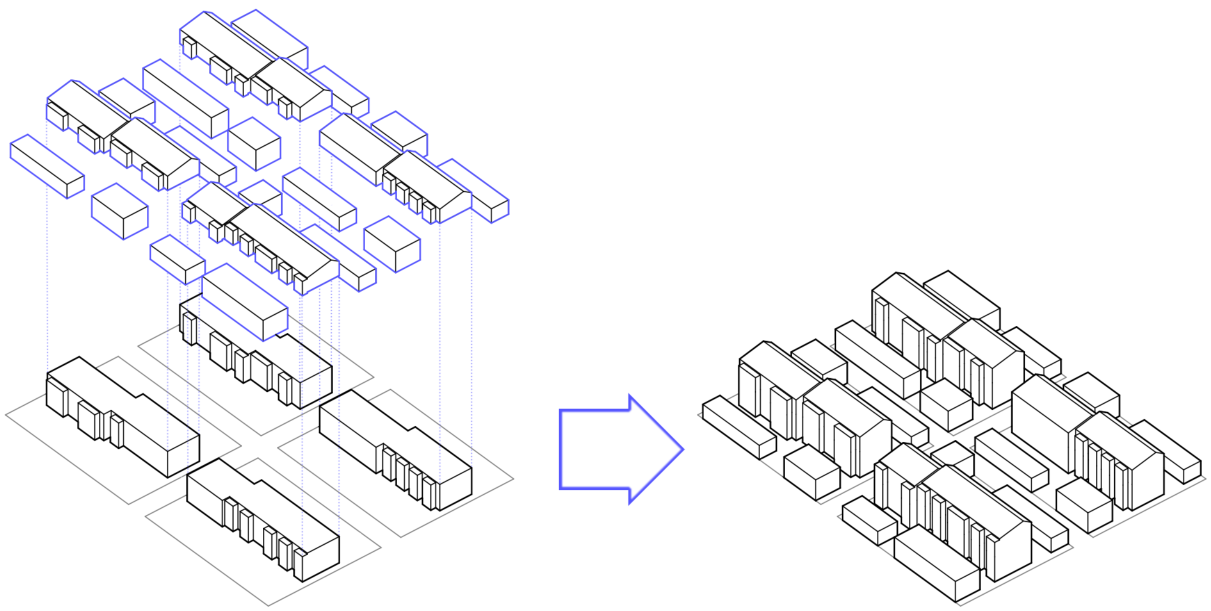
Since the current data quality of the existing building stock is of a rather rudimentary nature, new ways need to be discovered to make a more detailed analysis of the building stock. Previous research has shown ways of creating an analysis based on datasets from different sources, such as a research project in Belgium (Gepts, et al., 2019), where two datasets were combined and extrapolated in order to make estimations on average building volume and interior wall area of terraced and detached houses. These findings could potentially be applied on the existing building stock that might become available for reuse and recycling in the future. Another case proves that it is possible, and often beneficial, to combine several datasets, in order to characterize the material composition of a building stock (Kleeman, et al., 2016). A similar method can be used to quantify the urban material composition of Tampere, including information on construction techniques, age, material and quantity.

Continuously studying the urban metabolism and material stocks and flows are a valuable tool in order to adapt to changing patterns and to make up-to-date decisions (Augiseau & Barles, 2016). Also, by identifying the spatial distribution of buildings and their construction materials, the amount and composition of demolition waste could potentially be forecasted which helps to evaluate the costs arising in disposal (Kleeman, et al., 2016). So in addition to functioning as environmental impact tool, studying the urban metabolism can help making financial assessments and rough estimates of the several circular alternatives.

6.1.2 Potential of transforming the urban form

Before decisions are made to demolish and redevelop whole areas from scratch, urban form studies need to be undertaken to identify their typological transformation potential. The study has shown that it is often a conglomerate of buildings that gets demolished to make way for a series of new developments. In some cases, precautionary measures can avoid unnecessary demolition of a fit-for-infill urban type. Shortly after infill was identified as a feasible solution, observations on the building level need to clarify whether a building and its physical attributes allow changes in size and fuction (see chapter 6.2.1).

Today, the issue of urban transformation in times of social and environmental changes, is acknowledged as one of the fundamental challenges, architects and city planners will have to solve (Stojanovski, 2012). Its geographically difficult location has forced Tampere to take more drastic measures in order to deal with the steadily increasing population. In summer 2020, the city passed the masterplan for the Hiedanranta area, which includes a large housing complex built on an artificial island. Already today, freely available land is scarce and will become even rarer in the future. In order to avoid widespread demolition as seen in areas like Kaleva, Härmälä or Hatanpää, city planners need to begin identifying the urban transformation potential of the existing city structure.



6.1.3 Urban typology for transformation

Due to its geographical location, Tampere is spatially limited and will soon be dependent on densification in order to keep up with its steady growth. Because of that, areas for greenfield development such as Vuores, Muotiala or Lintuhytti will become more and more scarce and so it would be wise to develop strategies for urban typologies that allow densification with a minimised demolition effort. That means that urban development projects need to be planned ready for future transformation, i.e. densification and reduction without causing large amounts of demolition which were stirred by construction. That means that initially, a newly developed area can be made of a rather lose typology so long as the urban form allows typological adaptation.

These principles might as well be contradictory to paradigms of building resource-efficiently. For example, in order to design a loadbearing wall for additional floors, more material may be needed to be invested than required for its initial state. Also, there is a chance that these additional floors might never come which would mean that these extra materials were used for nothing. So, in order to avoid wasted material, preassessments need to be made on the probability of future densification, material use and whether it would make sense to design for e.g. additional floors.

Another challenging aspect of this new urban type is its ownership. An area that is designed for future densification needs to allow these changes whenever there is a need for it. While, especially in Finland, detached houses are most likely to be owned by an individual or a family, making massive changes to this building type, in fact, changing this building type almost completely to a denser typology, can become challenging in case the owner does not agree to it. One possibility would be to, instead of ownership, the city rents out land and lets the lessee know from the start that future infill is possible to happen.

An indicator that launches the densification development needs to be created, in order to determine the starting point where sufficient demand for extra space has been identified. For this, a tool can be created that helps identify changes in the market in order to avoid an oversupply. Based on changing demand, this tool can send an alarm that signals the need for adaptation which will launch transformation works.

Future land use planning in Tampere may then take the possibility into consideration to densify these areas instead of developing more greenfield areas. Keeping a higher number of green pockets in and around the city, bears the potential of an improved urban climate, higher levels of biodiversity and offers recreational activities for the citizens.

One of the most prominent examples for this approach are the social housing efforts by Chilean architect Alejandro Aravena. The idea of self-determined construction in developing countries however, had its origins already in the 1970s, when John Turner criticized the general notion of providing finished, low-cost housing for the low-income society. Instead, he argued that it would be much more efficient (and socially acceptable) to provide future residents with only parts of a house and mainly the tools to finish and customize their home to their own personal needs (Turner, 1974). Even though there is a large cultural, social and political difference between Finland and South America and building requires a whole different set of expertise, it is worthwhile identifying whether an urban typology for adaptation can also be established in the North. The idea behind Aravena's Quinta Monroy / ELEMENTAL came from the need of building affordably. Instead of making a finished building with a chosen set of installations, the architect decided to design only one half of the house which can be customized according the users' needs. Over time, when the users have acquired enough resources, they were then allowed to extend their house.

Quinta Monroy / ELEMENTAL – Alejandro Aravena

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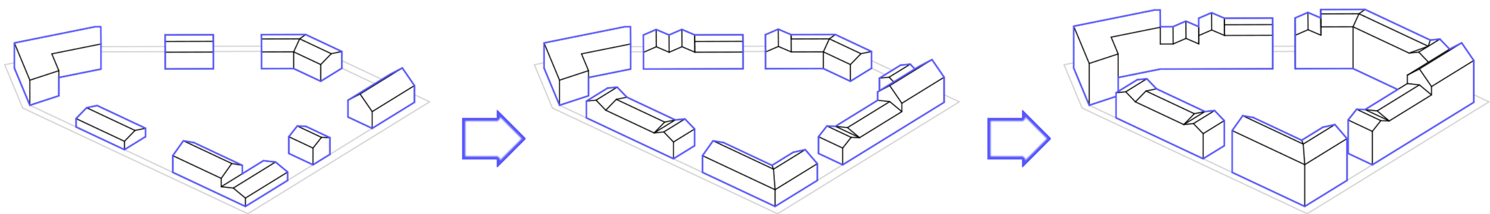


6.2 Building Scale

6.2.1 Spatial and functional adaptation

The natural transformation potential of buildings bears a great opportunity for maintaining the intrinsic value of existing buildings by adapting them to their new functional or spatial needs. Even though, housing in Tampere has a significantly lower risk of being demolished than for example commercially used buildings, there is a risk in the existing housing stock – especially from the 1960s and 1970s – to segregate due to a limited variety of housing types and sizes (Huuhka & Saarimaa, 2018). On the other hand, research found out that the existing Finnish housing stock often bears a natural potential of being adapted to changing spatial requirements (Kaasalainen & Huuhka, 2020). Additionally, Kaasalainen & Huuhka (2020) have developed a building stock approach to identify the potential for functional adaptability which can be applied for future research of, especially those building types, which are known to be replaced due to changing spatial and function requirements like the ones mentioned above. To express the potential of buildings to adapt to new functional and spatial requirements, the Transformation Capacity reflects on both technical and spatial aspects (BAMB, 2020) and can be used as a tool to communicate a building's capability to adapt.

“The greenest building is the one already built.”

(Carl Elefante, architect)

As found out in the study, the need for larger premises or changing functional requirements are one driving factor for demolition, i.e. the replacement of buildings. As demolition is usually regarded as an easier and cleaner solution, the natural transformation capacity of existing buildings often gets overseen and it seems to be generally underestimated. Before deciding on demolishing a building and replacing it with a new one, architects and clients need to start considering the existing structure and discover whether there might be a potential of reusing it for a new purpose. This applies especially for commercially and industrially used buildings in Tampere since they were found out to be the most common target for getting replaced with blocks of flats. By preparing those buildings for reuse and hence, saving their embodied material value, Tampere would be able to save up to 25% of its total waste generated by demolition.

Ahrensfeld Terraces in Berlin used to be a typical Soviet block of flats which struggled with increased vacancy. Renovation became unprofitable as 12% of the flats were unused and so the decision was made to partly dismantle the building while keeping the lower floors intact for residents (degewo AG, 2010). After 12 years and the realisation that Berlin is in urgent need of residential floor area, the building again offers the opportunity to be extended. This time though, floors theoretically could be added again back to their initial location.

Berlin Ahrensfeld during the renovation in 2008

©Kathrin Schubert

Berlin Ahrensfeld terraces

©Jens Rötzsch

The transformation of the old torpedo boat workshop in Copenhagen is a nice example of a complex adaptation task. In 2003, the Danish architecture firm Vandkunsten finished the transformation of the 1954-built reinforced concrete structure into housing units. The 67 flats vary in size from 75 to 275 sqm and were placed inside the existing structure. The project shows the natural transformation potential of building types that have seemingly nothing in common with the newly intended use.

New homes in the old torpedo boat workshop – Vandkunsten 2003

© Vandkunsten (above and below)

6.2.2 Assessment of building components fit for reuse

The existing buildings of Tampere have an untapped potential of becoming material banks. An analysis of the quality and quantity of building components used in the existing building stock can be used as the basis for a fit-for-reuse analysis. Based on construction technique, physical properties, age and material use, Tampere's buildings, i.e. building components need to be further analysed in order to become part of an urban building material cadastre (see chapter 6.2.3). Currently, several norms prohibit the use of reclaimed concrete panels for new blocks of flats in Finland which is often due to spatial requirements and building material's physical properties (Huuhka, et al., 2015). Acknowledging its material depot potential, Huuhka, et al. (2015) suggest, that precast concrete panels from the 1960s – 1980s could be reused for other building types such as detached houses. Even though, there is no standardization, dimensions of panels and slabs from this era in Finland are highly uniform which might offer an increased potential of replicable reuse methods. In Eastern Germany, which has a building stock of fully standardized panel systems, one of the key criteria of reusing e.g. precast concrete elements was found to be their ability of getting dis- and reassembled while their conditions are less often an obstacle for reuse (Asam, et al., 2005). As a next step, it is important to develop standardized testing procedures. In the research project "Plattenvereinigung" (panel merger), several methods have been tried out to test the material properties and potential for reassembly (from different building sources) of reclaimed concrete slabs (Vogdt, et al., 2016).

As field documentation of existing buildings can become extremely time consuming, 3D scanning methods with the help of lasers or photographs start to become of great value. With the help of flying drones, digital cameras and 3D modelling software, detailed 3D imagery of existing buildings, outdoors and indoors can be created. With the help of terrestrial laser scans (TLS), based on the surface of a material, researchers start to develop an approach in which even the material composition of a building can be identified (Yuan, et al., 2020). However, automated assessment tools have not yet reached a point where building components along with material composition and physical attributes can be measured which makes a comprehensive stock assessment, in reality, almost impossible. In order to spread out the heavy workload that comes with a comprehensive assessment of stock material, a pre-demolition protocol (Institute of Civil Engineers, 2008) can be established in order to quantify materials of buildings without material passport or BIM model, right before they become available.

6.2.3 Building Material Cadastre Tampere

One of the problems with construction materials, building products and components is that they are often not identifiable, especially on a large scale. In order to activate the potential of Tampere's building stock, a digital building cadastre is an excellent tool to make buildings and their construction materials more accessible.

The architect Thomas Rau proposes the idea of a material passport (Kaminski, 2019) for new buildings to give waste an identity. A material passport will have to become a requirement for all new construction in Tampere. It helps to keep track of the building material, its quantity, age, composition, physical properties, etc. The data will be updated for every transformation the building goes through, in order to keep its information in an up to date shape. Adding material passports to BIM models, which, in practice, are already a widespread technology among Tampere's architecture and construction firms, will create a powerful tool "to make the likelihood of good deconstruction, or even keeping a building, higher" (Duncan Baker-Brown).

The idea of creating a material bank for already existing buildings, which have no BIM models or information on used construction materials is a more complex task. Knowledge of the quality and quantity of ready-for-reuse buildings and materials however, is one key element of turning buildings into material banks. Therefore, material passports can also be acquired by owners of existing buildings to enable the reuse potential of their property and potentially increase their value. Bar codes, colour codes (Addis, 2008) or digital chips can help to trace and identify those materials and components later on site. In case a building is about to get demolished Pre-Demolition Audits can be used to make an inventory of construction materials and building components that accumulate during disassembly and to hence, to evaluate their recovery options (Wahlström, et al., 2019).

Through a detailed building database, owners are provided with a powerful tool to evaluate the building value and make qualified assumptions of the financial benefits from maintenance. In case a building's functional or spatial properties have become unsatisfactory, planners can create design scenarios that would help to make decisions whether functional or spatial adaptability are feasible.

"Waste is material without an identity"

(Thomas Rau, architect)

Once identified and catalogued, materials become a deposit and the building stock is the material bank. In other words, a cadastre functions as the link between disassembly and new construction where materials can be either deposited or withdrawn when needed while preserving their intrinsic value.

In many European countries, several companies have started to establish the idea of a material bank in their local environment which is most often situated in larger cities with a high urban material intensity. The online hub, which was created by the UK-Green Building Council (GBC) Future Leaders Programme, creates a marketplace for building materials and makes it openly accessible for clients, architects, designers and whoever show interest in reclaimed materials. Additionally, the platform works as a marketplace where users see materials that become available and may place a bid on them. Interestingly, UK-GBC has found out that building owners usually know about demolition already well in advance which allows to put those materials on the market with enough time for re-users to act (Cheshire, 2016). An urban resource cadastre was also the goal of a project in Odense, with the help of a material intensity coefficient and by separating construction materials by their location inside a building, the research created a good basis for future recycling of materials (Lanau & Liu, 2020).

Since its launch in 2019, Opalis (Rotor, 2019) is developing into a network of companies and individuals to offer surplus materials for sale. Users of the site can either browse the materials list or a specific location to see what is available in a certain area. Restado has a similar approach where users can search in categories for materials, they are looking for (restado.de, 2020). In this case, the location of materials is not part of the focus. In 2019, the Finnish company netlet has launched their online shop for surplus virgin materials from construction. The business model turns out to work as construction waste usually generates extra costs for the construction company while netlet offers to pick up those materials for free. By the end of 2019, they have harvested already 300 tonnes of valuable construction materials (Sitra, 2019).

While those approaches offer a great opportunity for those who are willing to share their construction materials, the overall potential has often not yet been made fully accessible and until today, reuse has a rather sporadic nature. With the credo of Install – Use – Recreate, Madaster strives to establish a cadastre of materials by documenting the identity of materials and generating continuous access to them (Madaster, 2020). The Urban Flows Observatory by the University of Sheffield is tapping into the same direction. In 2018, it launched a campaign where architects and designers were asked to share building data like use, structure, materials, connection types and construction period (Lanau & Densley Tingley, 2018).

There are many more attempts to create urban platforms for a circular treatment of construction materials. The one thing all those platforms have in common though, is that none of them is binding. Based on this research and with the knowledge gained from all those other attempts, Tampere has the unique opportunity to become the pioneer city of a mandatory construction material cadastre with a series of precautions:

•Launch actions to identify the material use of existing buildings (see chapter 6.1.1)

oMake the use of BIM models mandatory at a certain buil ding size

oUse of material passports (embedded in BIM)

oDemolition of buildings must be reported in Pre-Demo lition Audits

•Building, component and material platform

oUsers may place bids on buildings and materials

oThe reuse of a whole building must always be preferent ial, followed by the reuse of components and then mate rials

oOther materials which are not directly associated with construction such as structures, shipping containers, etc. may also be offered for reuse and upcycling

oAlarm system that notifies planners and designers that materials they need have become available

•Mandatory use for architects, construction companies, planners, etc.

•If virgin materials are used, proof that these or similar materials with similar properties were not available from the platform

•Building properties and used materials get marked as becoming available a certain time in advance in order to allow bidding and planning

•Aid demolition companies to shift their business model from demolition to disassembly

•Recertification of building products

•Establish an urban infrastructure that allows to store and move construction materials ready for reuse

Opalis Material Cadastre, Belgium – Rotor DB

www.opalis.eu/fr

The goals of the multidisciplinary practice Rotor are to "investigate the organisation of the material environment" (Rotor, 2016). In order to create a material platform, the team has visited and connected dozens of second-hand material dealers through a nationwide material platform. The site contains information and images of sellers as well as information of the construction materials that were sold. Since its launch in 2012, the site has been constantly updated.

A salvage yard for clay bricks

©Rotor

Old metal profiles being sold

©Rotor

Wood materials of all kinds are getting stored inside

©Rotor

6.2.4 Design for functional and spatial adaptability

The study has shown that most of the demolished floor area in Tampere were commercial & office, public, industrial buildings and warehouses that were replaced by housing and larger commercial & office units. Retrospectively, if these buildings would have been spatially and functionally flexible enough to be transformed to whatever new requirements were needed, this could have saved up to 25%, i.e. over 250 000 sqm of demolished floor area. Even though the study is explicitly no future prediction, an insufficient transformation capability is known to be one of the major drivers for buildings' short lifespan. To avoid demolition through replacement, buildings need to be designed and built so they can be easily adapted to changing spatial and functional requirements, according to the credo of "design for reuse" (DFR).

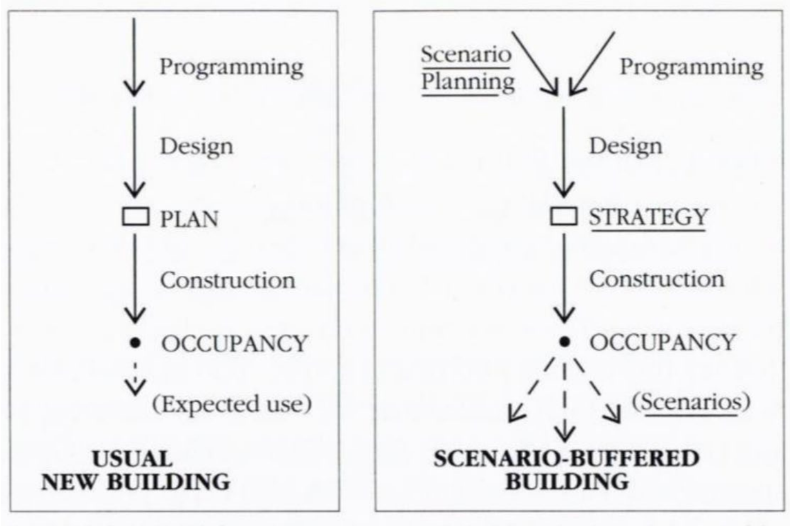
Today, building research is beginning to investigate the natural transformation potential of the Finnish housing stock (Kaasalainen & Huuhka, 2020; Huuhka & Saarimaa, 2018). Conclusions from such research will not only show which design strategies have 'accidentally' led to a higher level of adaptability but also, what needs to be considered more in depth when designing new buildings.

Designing buildings for adaptability comes with several obstacles. Not only do buildings of different types require different aesthetical assets, they also need to meet different spatial (horizontally and vertically) demands, energy performance standards and come with different installation types (water, heating, ventilation, electric, information, etc.). Based on historical evidence of the transformation of buildings however, there is hope for the next generation of buildings to be designed in a way that allows high levels of flexibility.

Stewart Brand (1995) proposes a series of measures which will help architects and planners in Tampere to shift towards a more adaptable and transformable built environment:

Previously introduced (see chapter 2), the design in shearing layers comes also in play at this point. The different life expectations, ownership and therefore different transformation behaviour and frequency of the different building layers makes it important to keep separated in order to allow the change of one layer without necessarily affecting the other. In practice, the Space Plan of a building must be transformable without making extensive changes to the Structure Not keeping that in mind complicates the inevitable transformation of buildings and makes them impractical and unprofitable.

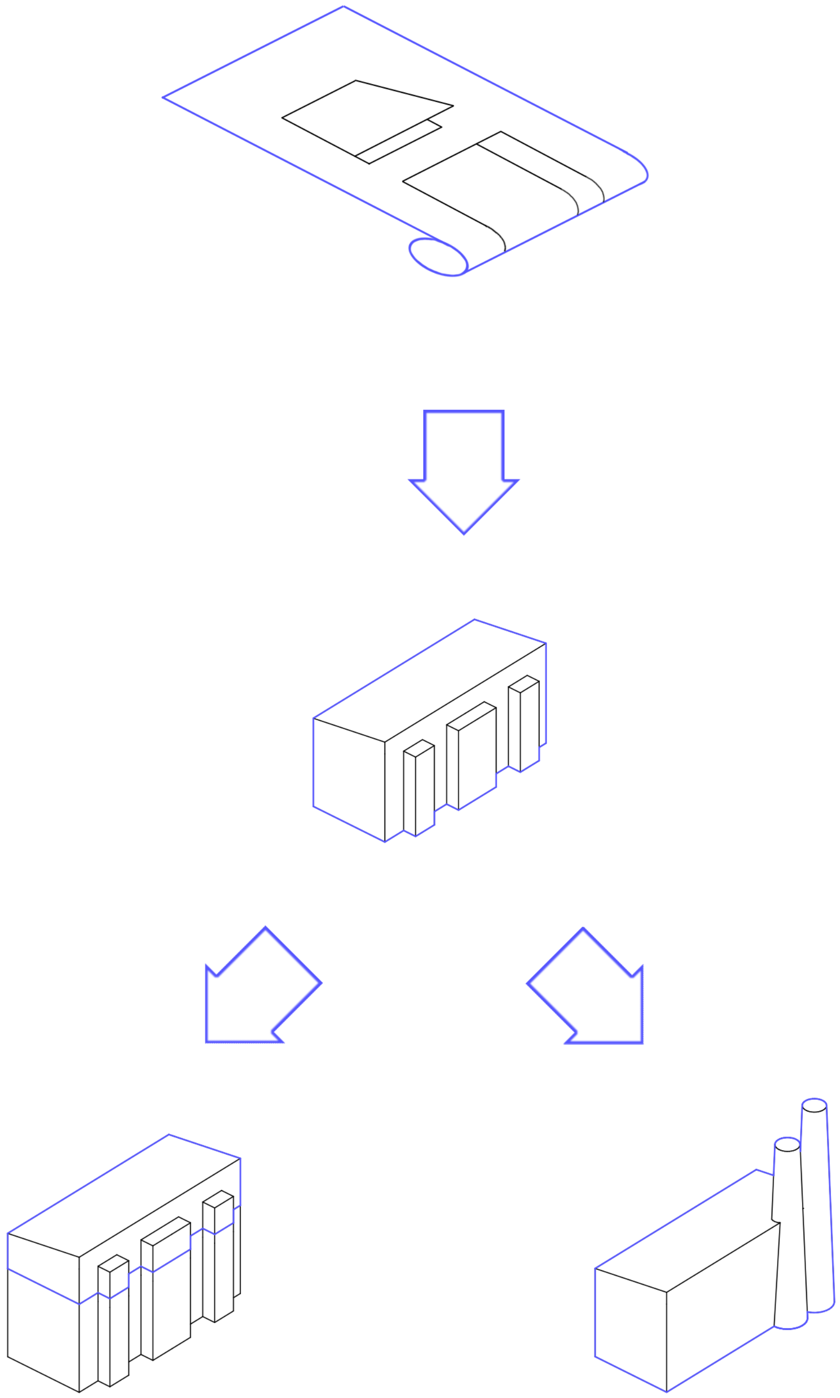
The idea of scenario planning has been part of military or business strategies already for over half a decade. In architecture, is has found little to no recognition to date. Brand (1995) introduces the idea that, instead of designing buildings based on a certain prediction (and often narrow, wishful future outlook), strategic scenario planning offers a series of variables with different unpredictable outcomes for which a building must be prepared. "A good strategy ensures that, not matter what happens, you always have maneuvering room" (Brand, 1995 p. 178) which means that whatever happens, the building is flexible enough to have an answer for any future outcome.



Scenario Planning (Brand, 1995)

Finally, simplified plan forms and the avoidance of complex forms usually makes them easier to adapt for changing layouts and functions. Brand (1995) claims that rectangular floor plans are much easier to adapt to new functions and layouts. Also, column-beam grid structures (Brand, 1995) and wide open spaces are usually much easier to transform than loadbearing walls which are more difficult to change (The American Institute of Architects, 2020). Moreover, generous floor-to-floor heights allow a flexible change from one function to another; a stronger structural system does not only allow retrofitting but also flexible change of openings. Clear documentation in BIM simplifies the possibilities for flexible change that future users and architects will have (The American Institute of Architects, 2020). In summary, generic space plans, though not an architect's favourite, offer a higher level of adaptation than very customised ones.

Besides functional adaptation, buildings need to be flexible in size. Designing buildings with the possibility to increase or decrease their size avoids demolition due to changing spatial requirements. In more detail, spatial adaptability means that, in the case of an increased demand, extra floors (vertical extension) or annexes (horizontal extension) can be added in order to create more building floor area. Vice versa, in the case of shrinking demand, buildings need to be fit for reduction, i.e. partial dismantling. Heavy emigration is unlikely to happen in Tampere in a foreseeable future, nevertheless it is a design strategy to consider in order to be prepared for the unexpected.



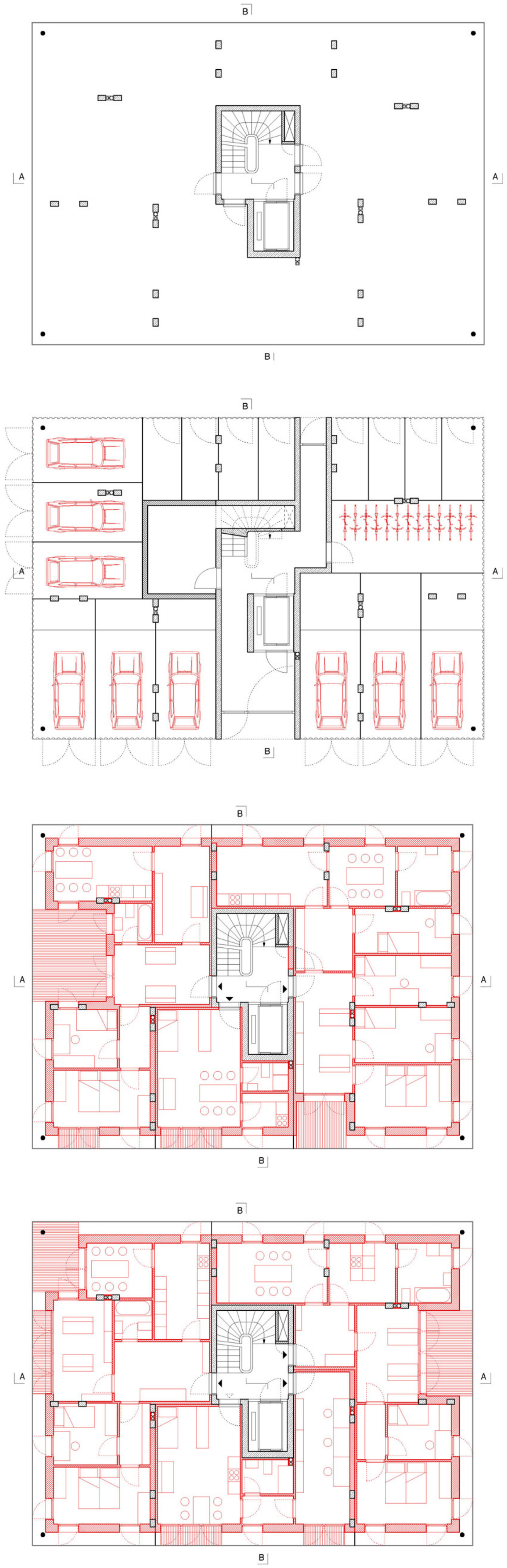
Completion of the base structure, 2013

©BeL, Sozietät für Architektur

Grundbau und Siedler, Self-Building Housing, Hamburg – BeL Sozietät für Architektur, 2013

©Veit Landwehr

The project Grundbau und Siedler by BeL Sozietät für Architektur explores the possibilities of low-income groups to become property owners. The goal was to achieve a project with an extremely high level of flexibility in order to allow the users to create spaces according to their own needs and financial resources. The high potential for future transformation makes it an excellent example of design for functional and spatial adaptability.



Highly flexible floor plans (right)

©BeL, Sozietät für Architektur

6.2.5 Design out of reused and recycled (construction) components and materials

The study has given a brief overview of the newly installed, existing and disposed construction materials in Tampere. With a 65%-share of the total stock floor area and more than three quarters of newly built floor area, concrete is the most frequently used construction material in Tampere. Over 30% demolished floor area was made of concrete while concrete buildings were demolished after only 36 years, which is a surprisingly short amount of time for such a rock-solid construction material. Highest carbon intensity paired with an alarmingly short lifespan of only 23 years, steel buildings are the youngest ones at time of demolition, peaking in steel warehouses, which are demolished after only 16 years. Those materials have gone to waste mainly because they were regarded as waste after their building's end-of-life. So, the question arises, what if we don't consider those materials as waste but rather as resource?

The reuse of previously used construction material can be divided in three different methods (Gorgolewski, 2008):

1. The reuse of an existing structure possibly includes spatial extension and a change of function. What is called adaptive reuse is relatively common with heritage buildings.

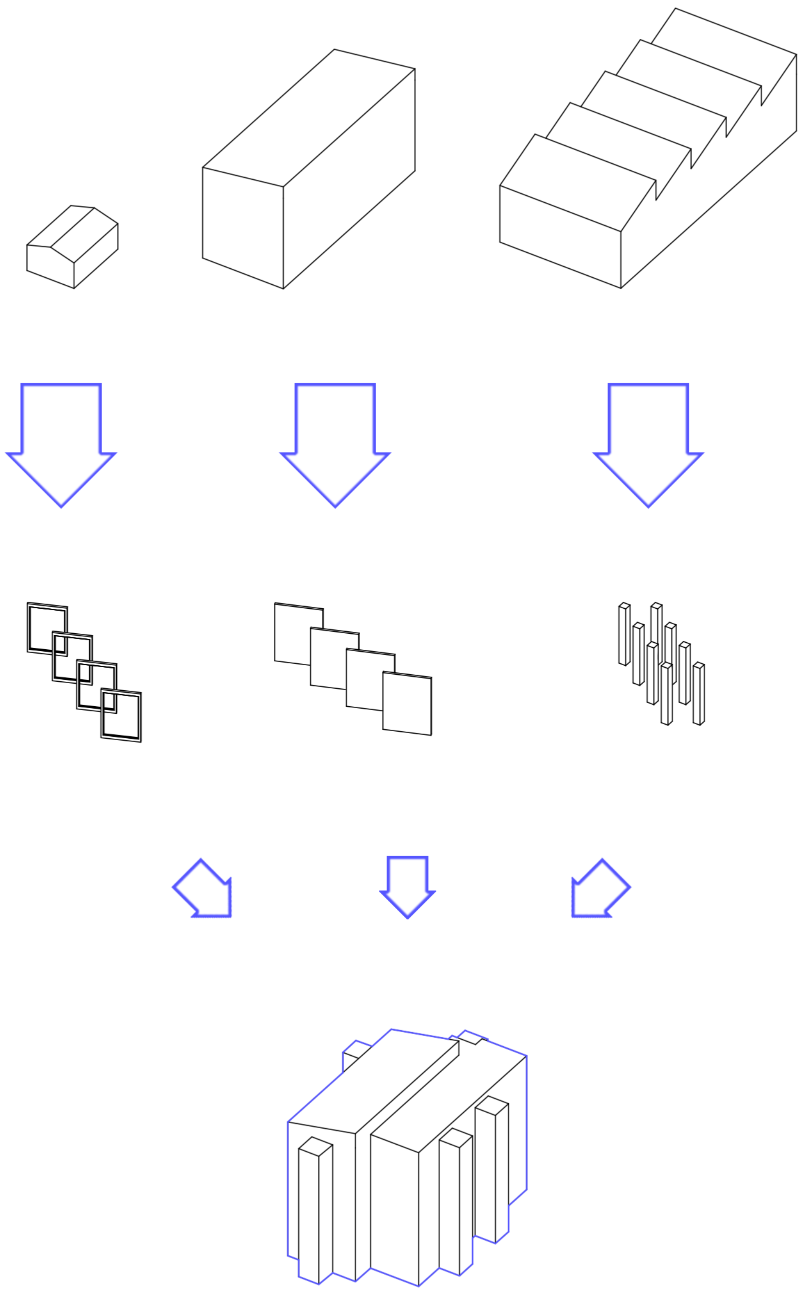
2. Disassembly of a building and reassembly on another location might be one of the oldest forms of mobile living and is used today for temporary structures like installations or stages. For buildings which are considered to be permanent, relocation can be considered in case the initial location doesn't suit the location anymore and a change in function is impossible.

3. Finally, component reuse is the use of single already used building products. It is especially suitable for prefabricated elements such as beams, columns and staircases but also bricks, windows and doors.

The reuse of building components often has an improved environmental impact than recycling since it usually means a reduced manufacturing process (it is not zero though, extra glasses might have to be added, a rotten part of the frame might need to be replaced, etc.). However, it also means a greater effort during the design process as the dimensioning and properties of components can't usually be changed. In order to design out of reused building components, designers must be ready to adapt their design approaches as the components might not be readily available and their measurements, physical and visual conditions are often unknown. On top of an increased complexity during the design task come challenges in the current industrial practice. Demolition is the most common, fastest and easiest way to deal with a building after it has reached its end of life. From today's perspective, reuse of components means an extra effort as it requires careful disassembly and further assessment. One of the goals, therefore, is to make the reuse of components a standardized procedure (Catalli & Williams, 2001).

In order to make the reuse of buildings easier, materials need to be recorded in an inventory and made ready for distribution. Creating Material Passports for existing buildings and recording demolished ones through pre-demolition audits (see chapter 6.2.3) might close the gap between the salvage contractor and the construction firm, hence the designer. The time gap between disassembly, design and new construction (not to speak of logistical gaps like the storage) however, are another issue especially for cash flow (Gorgolewski, 2008) and testing procedures need to be developed to certify components' and materials' physical quality (see chapter 6.2.2).

Despite its many challenges, reuse of building components has tremendous environmental advantages and needs to be more considered during the design of new buildings in Tampere.



The disassembly of the an brick wall

©Lendager Group

A built example for reusing building components was designed by the Danish firm Lendager Goup. In their project The Resource Rows, they reuse cut out brick panels from the nearby brewery building as a kind of patchwork façade material. Reusing those bricks became unprofitable, as the cement-based mortar is too hard to extract the bricks without severely damaging them.

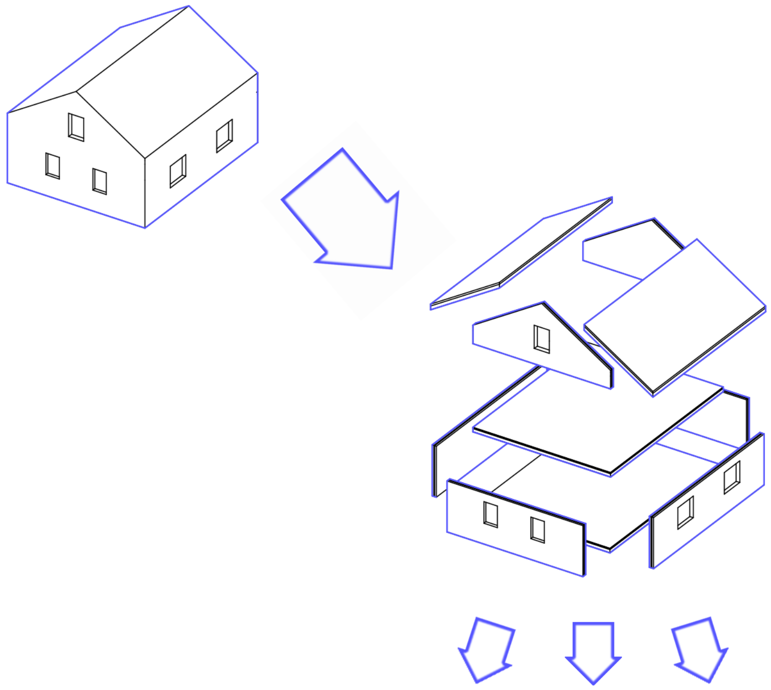
Resource Rows – Lendager Group, 2020

©Ditte Lysgaard Vind

6.2.6 Design for disassembly (DFD) and reuse of components

Especially large buildings were found out to be demolished after a very short lifespan. Those include commercial & office, public, industrial agricultural and transport buildings but also warehouses which make more than 75% of demolished floor area and got demolished after as little as 37 years. The extend of this wasteful demolition behaviour requires another drastic rethinking in how buildings and components are manufactured and assembled. In case the adaptive reuse of buildings (see chapter XXX) is no option, they need to be fit for disassembly and reuse of their building components. Fortunately, many of the aforementioned building types are already quite easily disassemblable, especially hall-type structures. Often, the connections of their building components are bolted, not cast, and there are no specific noise insulation requirements for the connections as in housing for example. The "soft stripping of a building" is the process of selective pre-demolition disassembly of components and materials (Isiadinso, et al., 2006), typically beginning with the interior, i.e. Stuff, often including the Service layer of a building which seem to have a natural potential for disassembly and reuse. The question arises, how can that potential be extended to the other shearing layers of a building? So far, disassembly of buildings with conventional construction techniques and their costs have prevented the industry from large scale deconstruction and reuse practices (Isiadinso, et al., 2006). The disassembly and reuse of buildings requires a rethinking in the industry and during the design of buildings. Generally, it requires thinking beyond the manufacturing and use of a building and its components.

Generally, an increased level of standardization is discovered to be of great value for the reuse capacity of components (ARUP and CIOB, 2013). Mechanical, easily accessible and reversible (i.e. no chemical connections that cannot be undone like gluing or welding) joint technology and easily separable layers (see chapter XXX) ease the process of disassembly and installation tremendously (The American Institute of Architects, 2020; ARUP and CIOB, 2013). The use of standardized measures, considering the handling of the components, and a reduced number of different component types through e.g. modular and prefabricated construction supports the design with reused materials (Addis & Schouten, 2004). The Multi-Space concept by 3DReid (see chapter XXX) is an excellent starting point for designers to think in modular and standardized techniques that support reuse. The material quality is one crucial aspect when choosing reusable components. They need to be durable to ensure their physical quality and an appropriate market value for reuse (The American Institute of Architects, 2020). After dismantling, standardized procedures for testing the elements whether they are fit for reuse need to be reliable, affordable and quick in order not to disrupt the workflow (see chapter XXX). One of the most crucial aspects in designing buildings for component reuse is, however, the identification of the materials. Through demolition, their value gets lost forever. BIM models, material passports or pre-demolition audits (see chapter XXX) on the other hand, become valuable mechanisms in combination with disassembly, in order to allow quick access to a building's valuable components (The American Institute of Architects, 2020; Addis, 2008). Building information must be safeguarded and maintained in order to ensure a high quality. A deconstruction manual may also support the process of disassembling for workers but also future owners of a building (The American Institute of Architects, 2020; Addis, 2008).



Built in 2000 in Stuttgart, Germany, The R128 House is one example of how buildings can be fully designed out of disassemblable building components. An easy mortice-and-tenon and bolted joint systems allows the steel and glass structure to be fully dismantled and reassembled for other purposes. Even though the embodied energy of the chosen building components is relatively high, their potentially increased life span and reusability justifies their use.

R128 House, interior – Werner Sobek, 2000

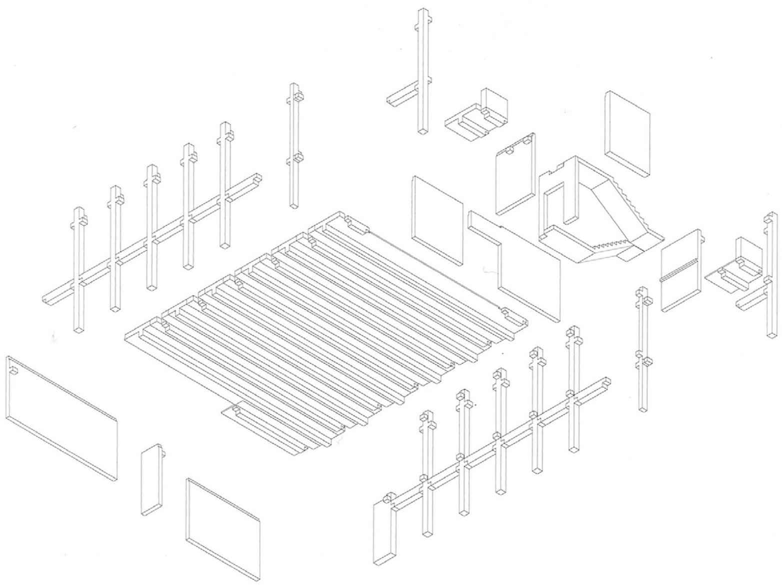
© Zooey Braun & Roland Halbe

R128 House – Werner Sobek, 2000

© Zooey Braun & Roland Halbe

Prefabricated concrete elements as found in the construction of industrial warehouses

©DETAIL magazine 6.2020



Not explicitly designed for disassembly and reuse, “Wohnregal” by FAR rohn&rojas shows the ability of designing a residential building out of prefabricated elements which are commonly used in the construction of industrial warehouses. Considering the short lifespan of those buildings in Tampere, this approach bears a great potential.

Wohnregal

FAR rohn&rojas, 2019

©David von Becker

6.2.7 Consider embodied energy in all building life phases

Ultimately, the embodied energy of construction materials needs to be considered throughout all life span phases of buildings. Whenever possible (with regards to previous design strategies), the construction material with lowest embodied carbon must be used. Life Cycle Assessments (LCAs) are calculation tools that help designers to calculate which material choices cause the least amount of embodied energy while considering the material intensity, operational energy, expected life span of a building, etc. In LCAs, the embodied energy of a building, based on product databases like the Environmental Product Database (EPD) or the Inventory of Carbon and Energy (ICE) gets calculated. Other environmental factors like transportation emissions are often handled differently, depending on the LCA calculation tool that was used which is why today, the most reliable results can be achieved by using several LCA calculation tools and comparing their results.

Calculating the embodied energy of a building helps to understand the importance of previously discussed design, construction and manufacturing strategies. These can be combined with the calculations to discover which approach is the most environmentally friendly, whether it is reusing that empty building which stands close by, designing a new structure with reclaimed panels or making a highly flexible building from scratch.

6.3 Zoom Area Kaleva

The following chapter is a zoom area of one of the previously identified replacement clusters (see chapter 4.3). Due to its examplary character, high demolition of especially industrially and commercially used premises and high construcion of especially blocks of flats, Kaleva was chosen as the ideal case study.

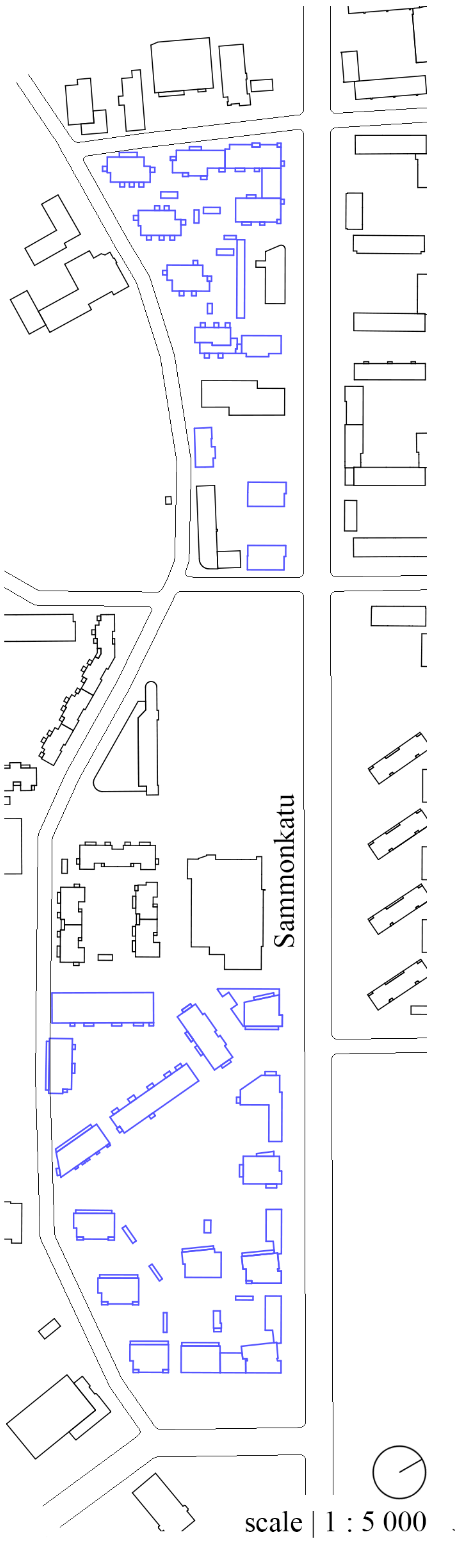
First, the demolished buildings were analysed. Since the existing data doesn't cover the demolished buildings' footprints, those were retreived from old town plans and aerial photographs. Further information for individual buildings was gathered from archival reserach. The demolished buildings were studied and selected for their theoretical potential of being spatially and functionally transformed.

The result is an alternative plan that shows which buildings could have been kept while still achieving a high urban density of residential buildings. Buildings that were not considered of being fit for adaptation were either analysed for their potential of getting disassembled or demolished and recycled.

aerial photograph Kaleva, 1995

aerial photograph Kaleva, 2018

Kaleva, Tampere Development 2000 - 2018

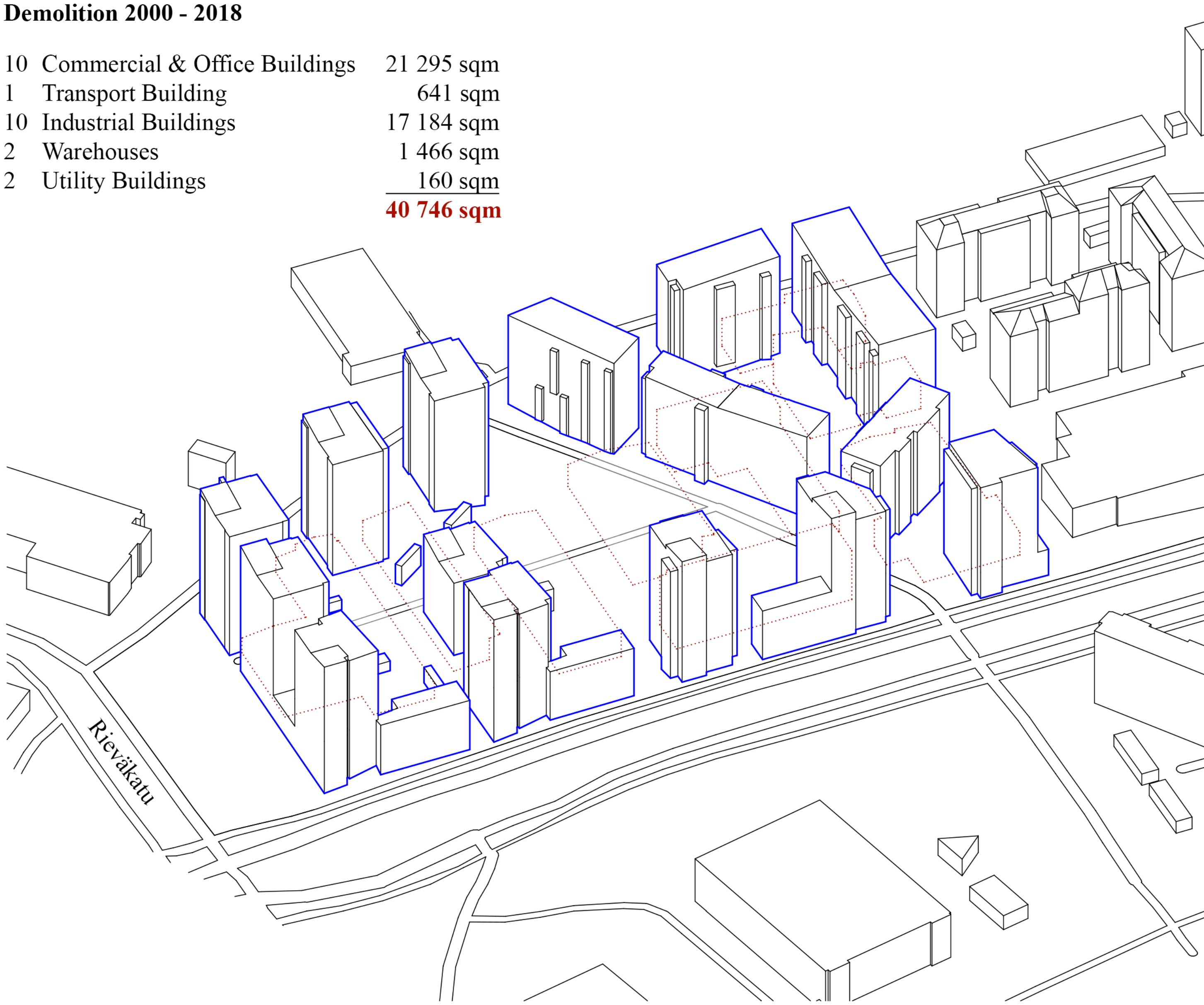


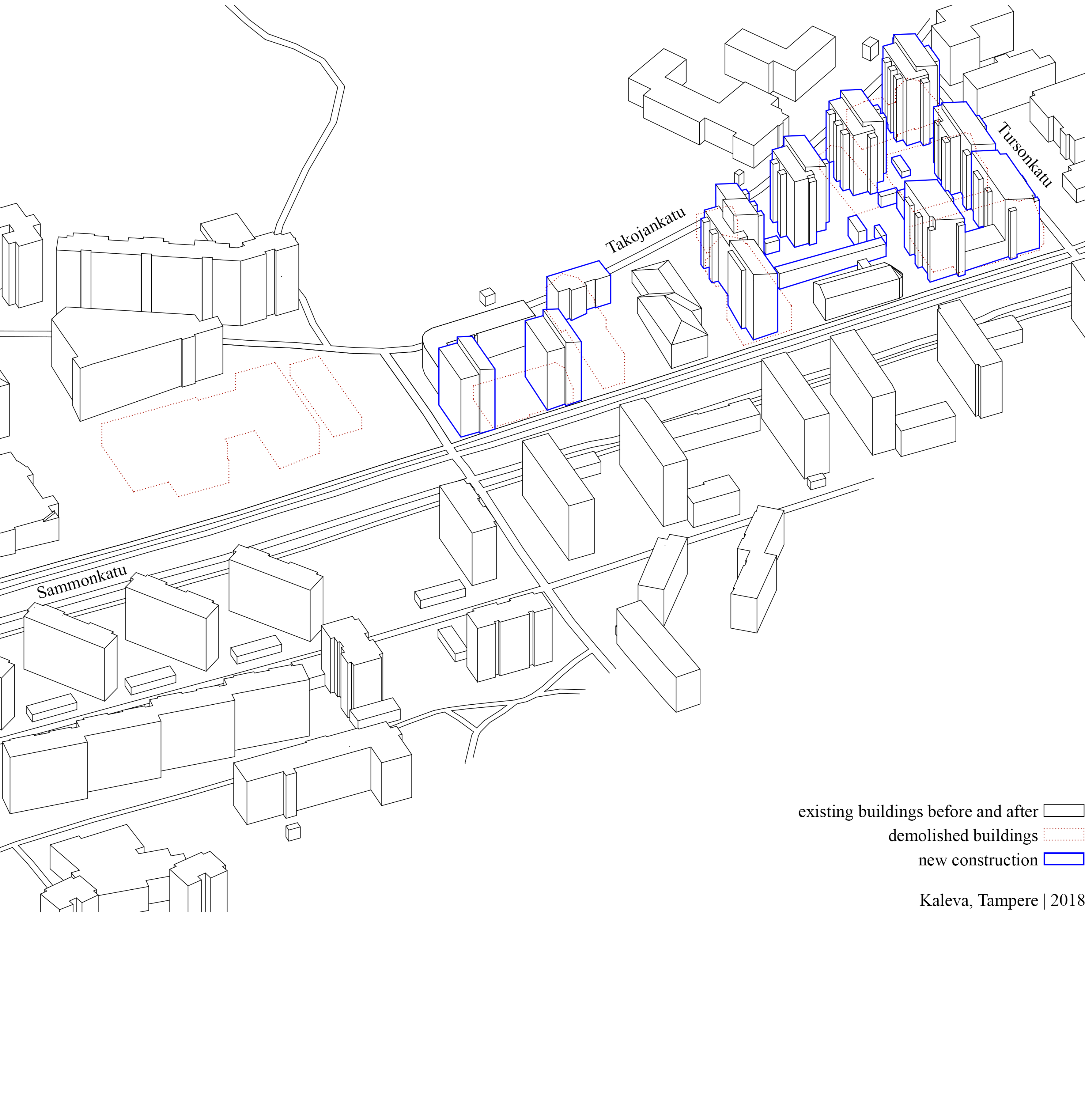
Construction 2000 - 2018

24	Blocks of Flats	83 472 sqm
1	Dormitory	6 600 sqm
1	Commercial & Office Building	5 691 sqm
2	Transport Buildings	3 895 sqm
3	Utility Buildings	88 sqm
		99 746 sqm

Demolition 2000 - 2018

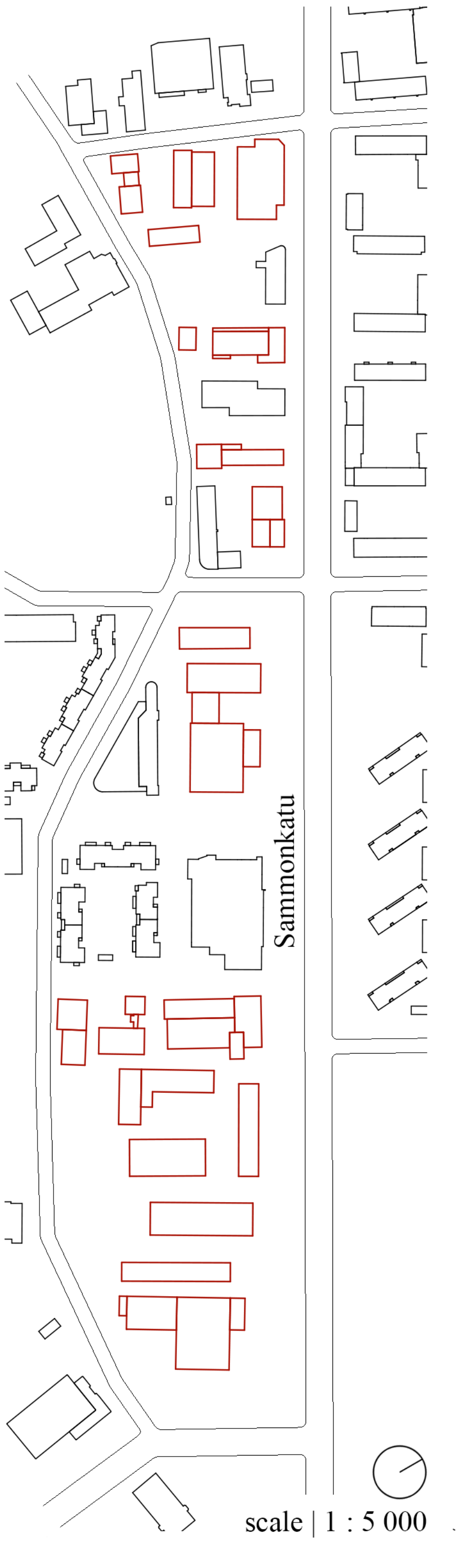
10	Commercial & Office Buildings	21 295 sqm
1	Transport Building	641 sqm
10	Industrial Buildings	17 184 sqm
2	Warehouses	1 466 sqm
2	Utility Buildings	160 sqm
		40 746 sqm





Kaleva, Tampere | 2018

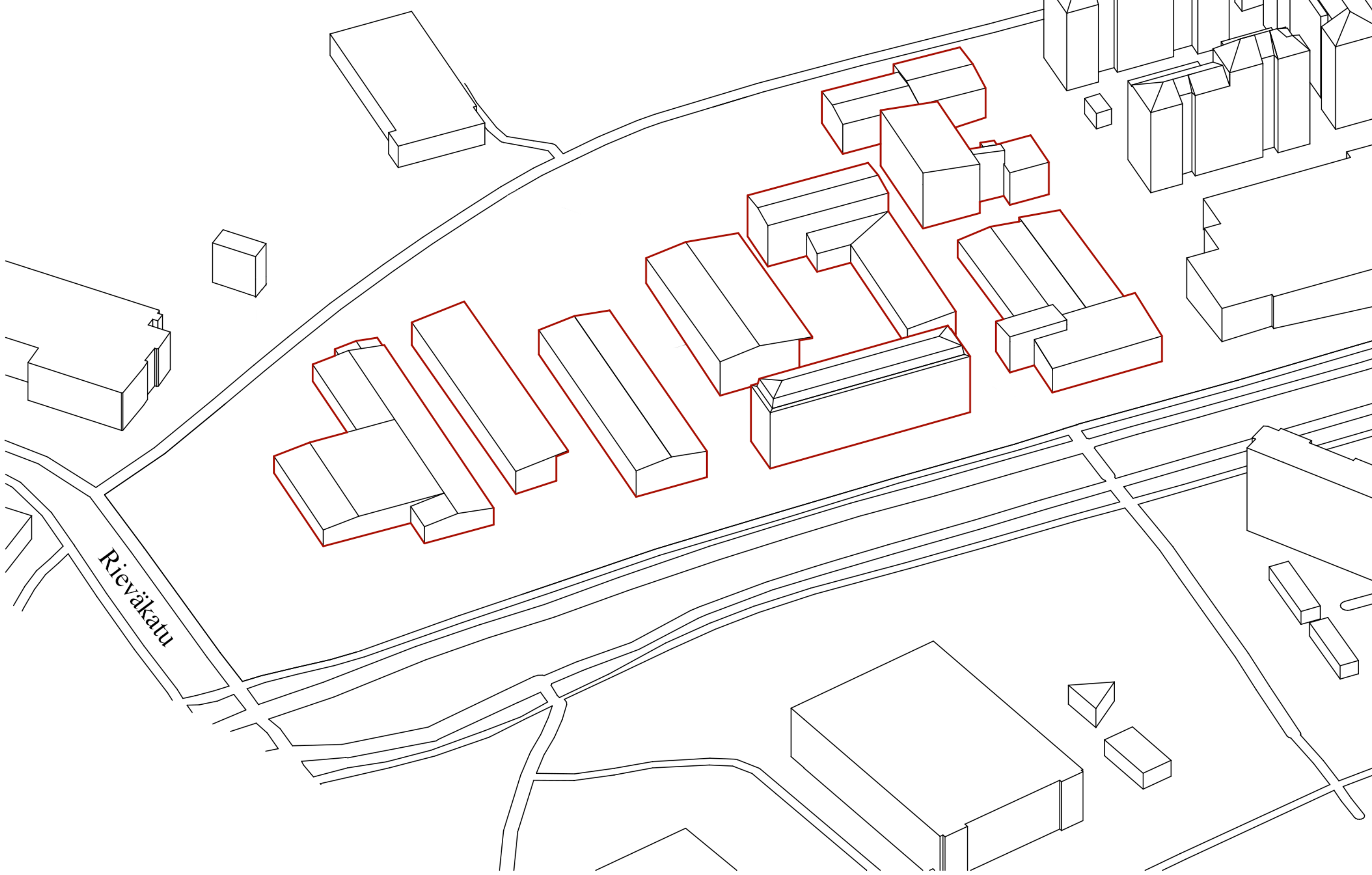
Kaleva, Tampere Demolished Buildings

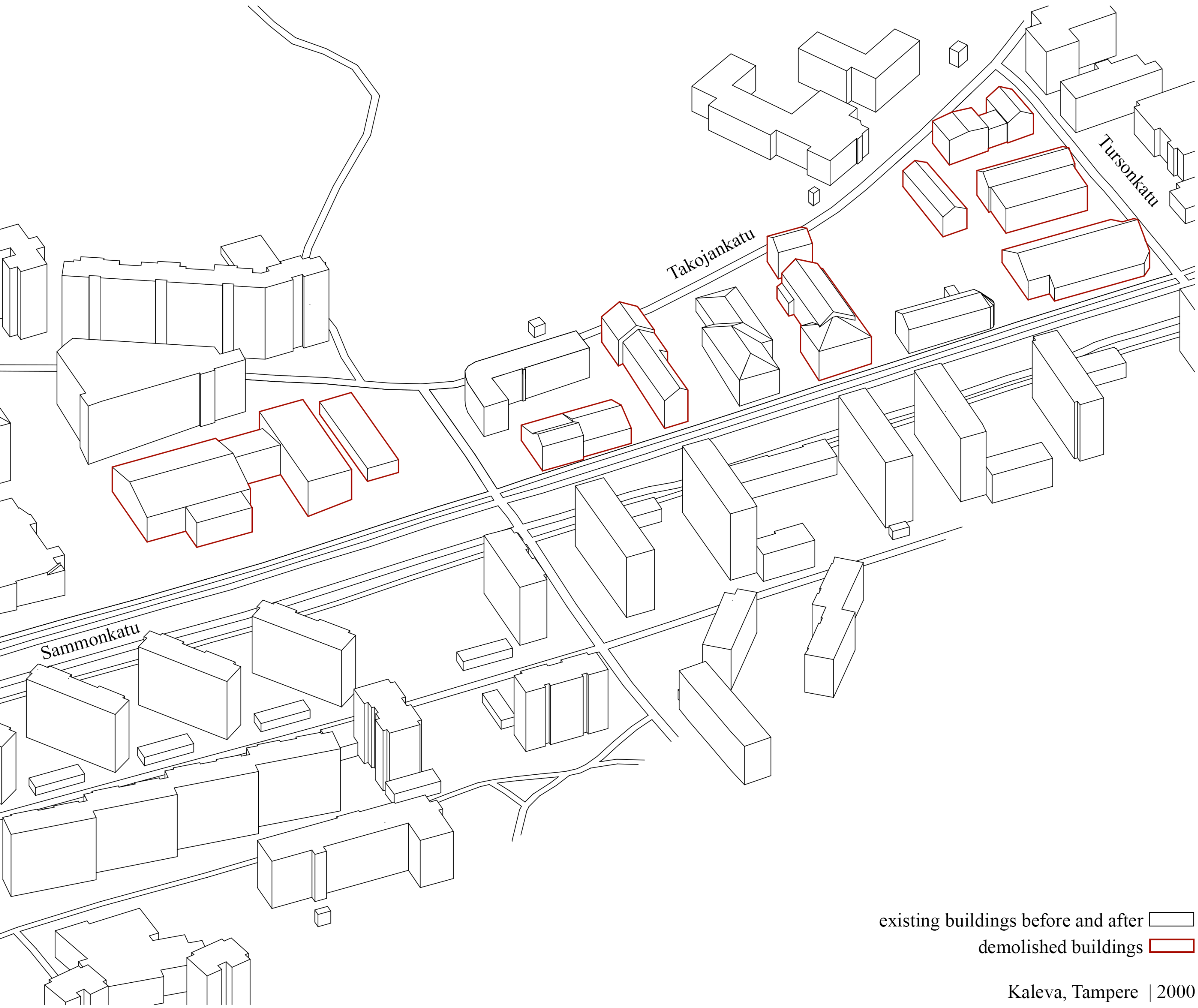


In 2000, the area south of Sammonkatu, Kaleva was mainly used as commercial area. A mix of functions from heavy to light industry, and commercial and office functions contrasted the residentially used area on the other side of the street. Most of the existing buildings were built in the 1950s and 1960s, often out of brick, concrete or steel.

Due to increasing numbers of residentis in Tampere, the area was chosen to be developed into housing which caused mass demolition of the existing buildings. Since it hasn’t been the buildings’ phyiscal conditions that caused them to be replaced, it can be suspected that the building materials and components were in reasonably good condition at the time of demolition. On top of that, many of the existing buildings’ spatial attributes might have allowed functional adaptation. However, between 2007 and 2018, all those buildings were demolished, disregarding their qualities and (material) values.

The following buildings show exemplary the untapped potential of existing buildings and how that could be used.



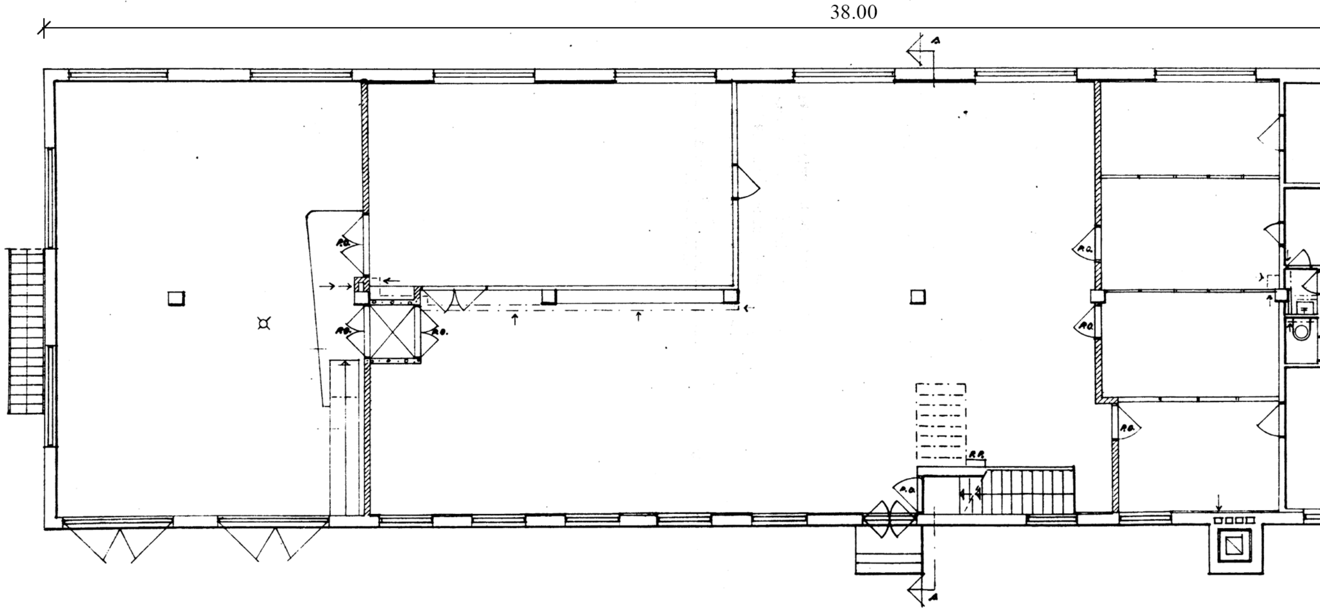


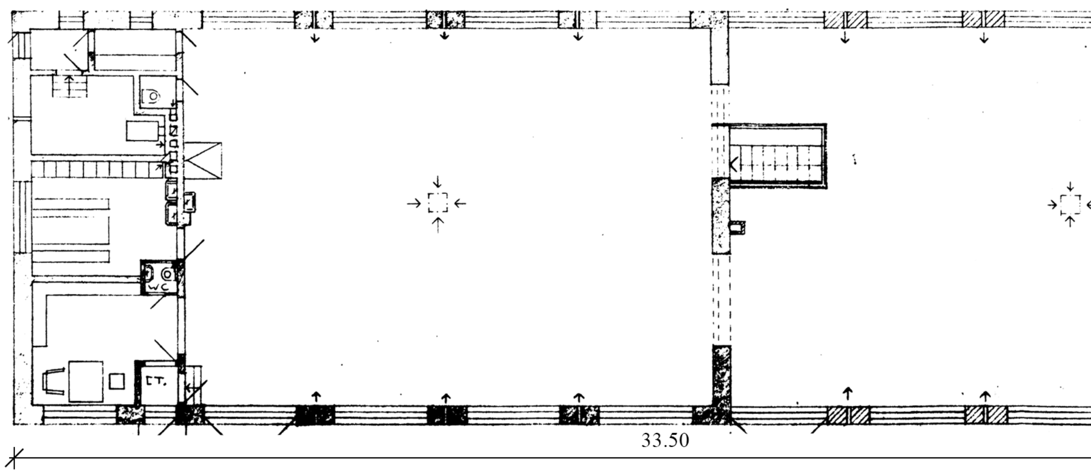
existing buildings before and after

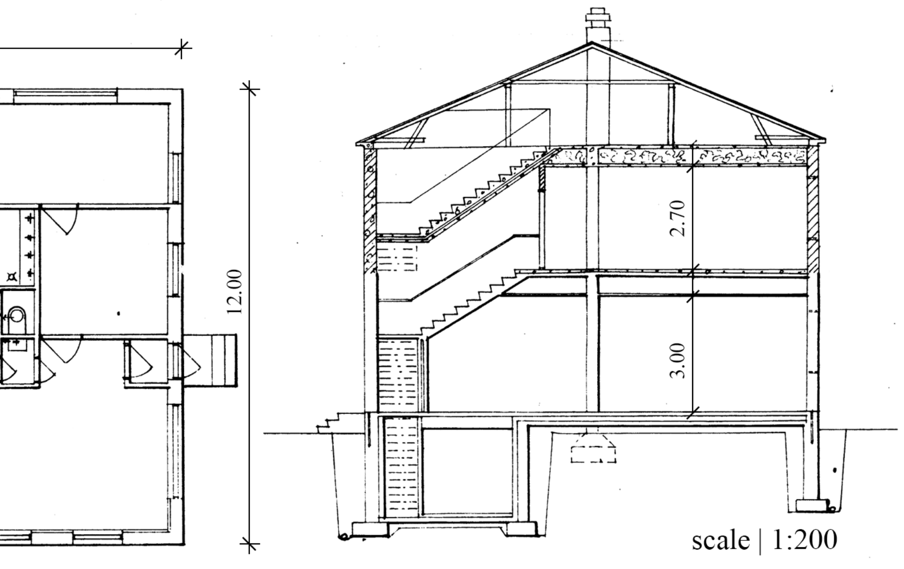
demolished buildings

Kaleva, Tampere | 2000

Kaleva, Tampere Demolished Buildings

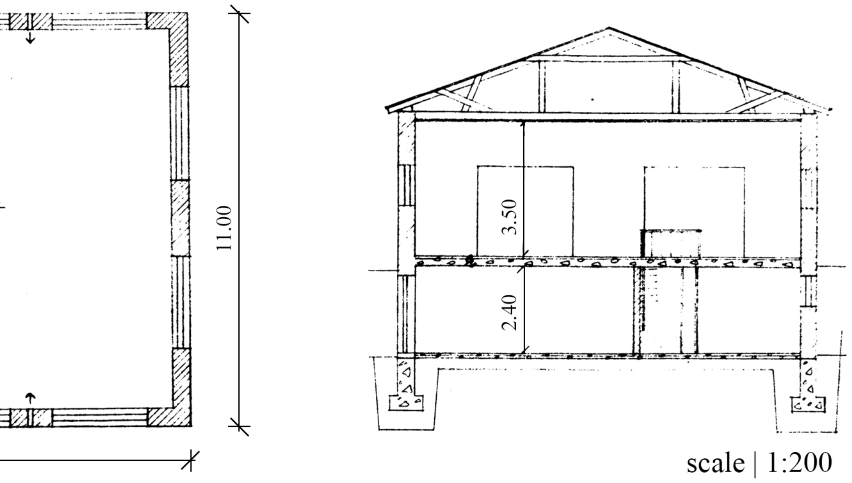






Building 1 used to be an old factory building with a gross floor area of 1 846 sqm. The brick building was erected in 1956 and after 52 years, it was decided to demolish the building to make way for new construction.

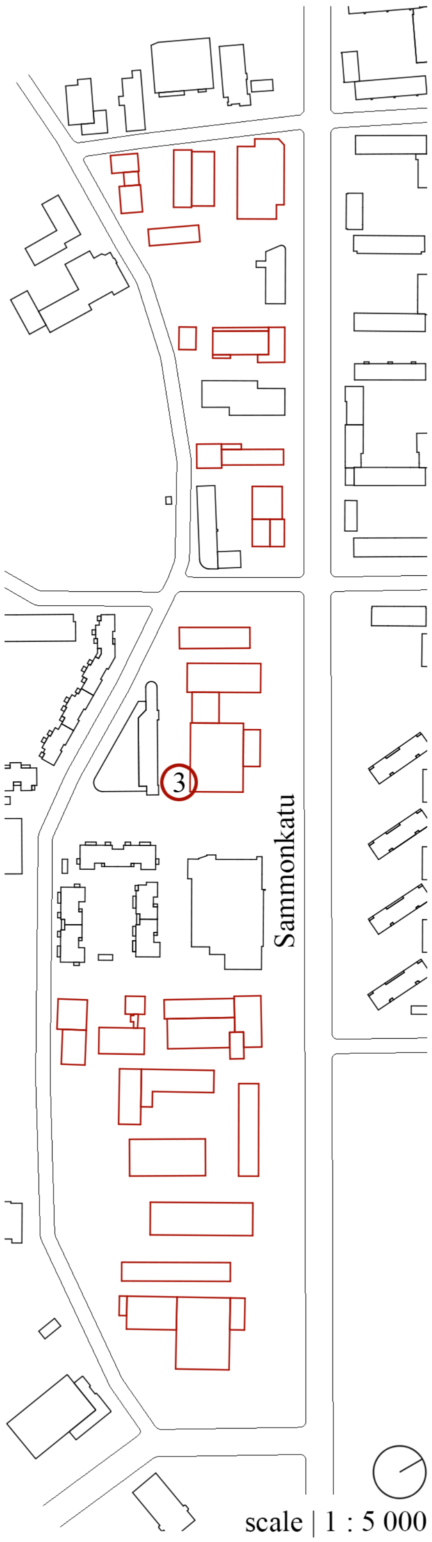
Instead of demolition, the main building might have had the potential to be transformed into a residential function. Floor heights and building depth are suitable and due to its massive brick structure, potentially, one or two floors could have been added on top.

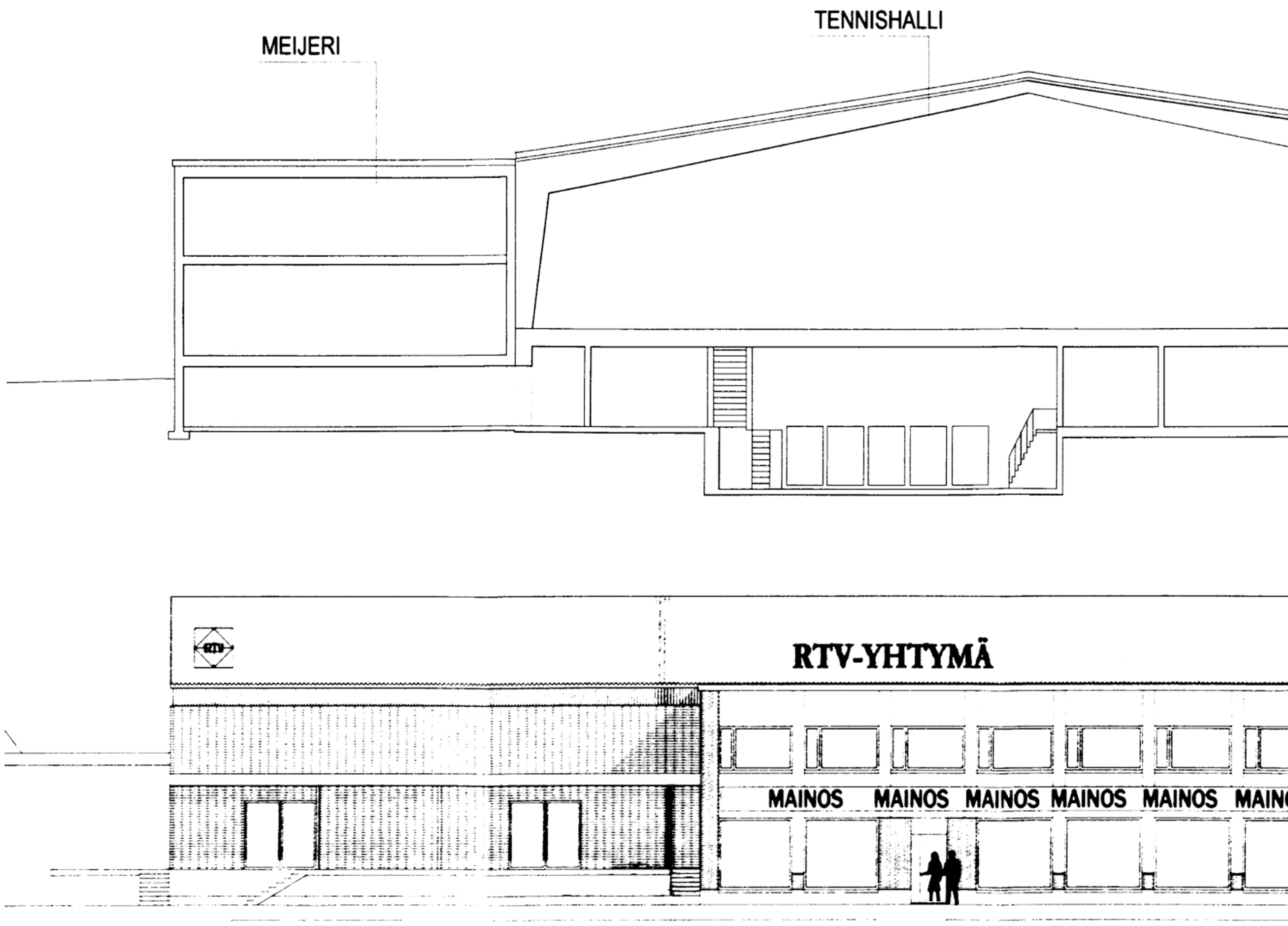


Building 2 was a small industrial building with a gross floor area of 600 sqm. The brick building was built in 1953 and demolished in 2008. It was replaced by a larger residential building.

The building had suitable measurements to be used for a residential function. Room depths and floor heights allow free positioning of living spaces without creating too dark unhabitable corners. Due to its massive brick structure, it might have had the potential to be extended by one or two floors.

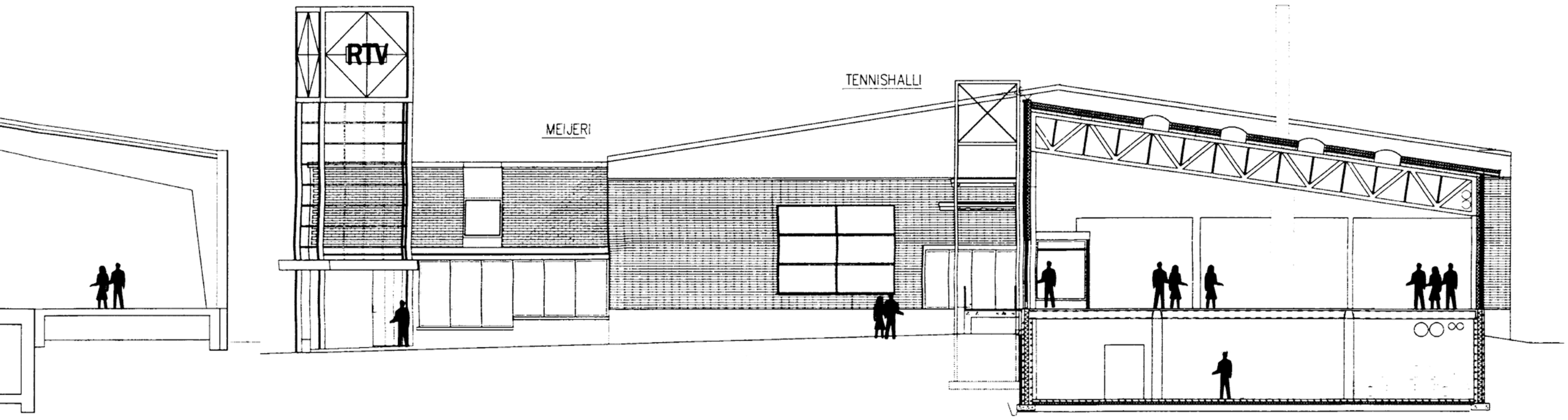
Kaleva, Tampere Demolished Buildings

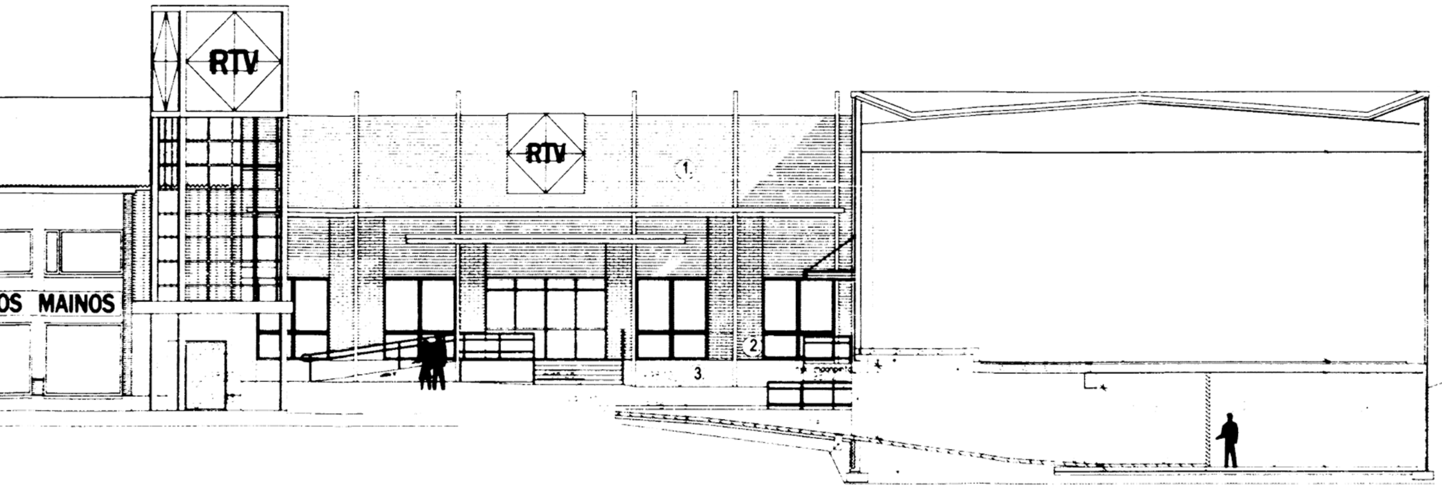




Building 3 used to be a mixed-function building. It was recorded as a store building but while it was operating, it was also used as a tennis hall and dairy. The original hall structure was built in 1965 and eventually accumulated to over 4 000 sqm gross floor area. After 53 years in use, it was demolished in 2018 to make way for TOAS student housing.

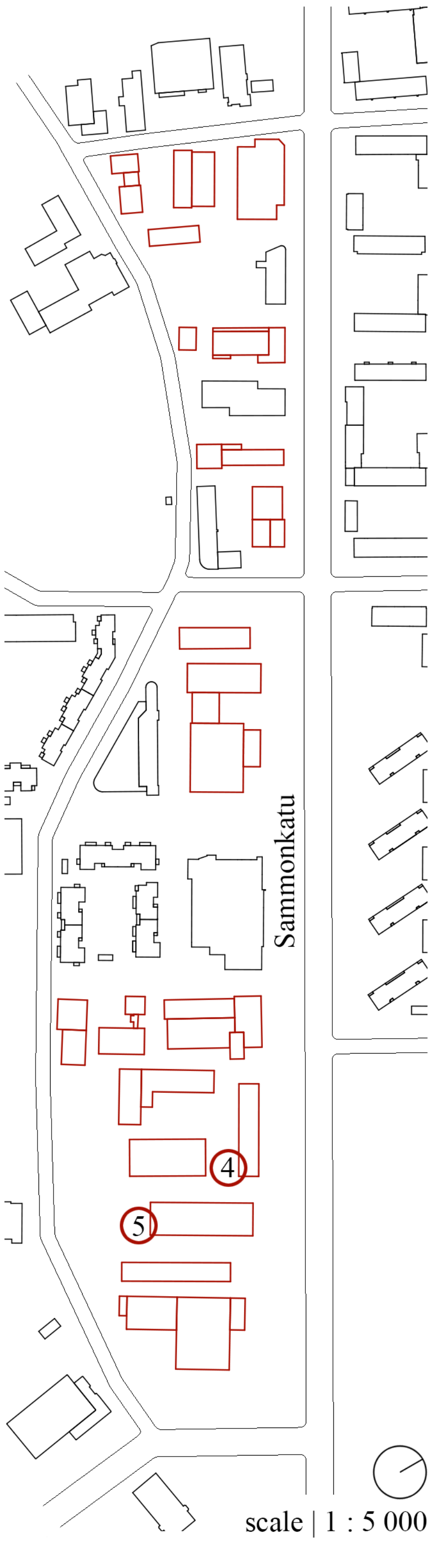
The building was marked as a steel structure but it seems that the different building parts had slightly different structural systems and components which are clearly visible in the section drawings. Instead of demolition, those building components could have been disassembled and reused for the construction of another building. In 2020, very close to the site, a commercially used building was built. Only two years after demolition, the components could have been reused for the new construction of that building.

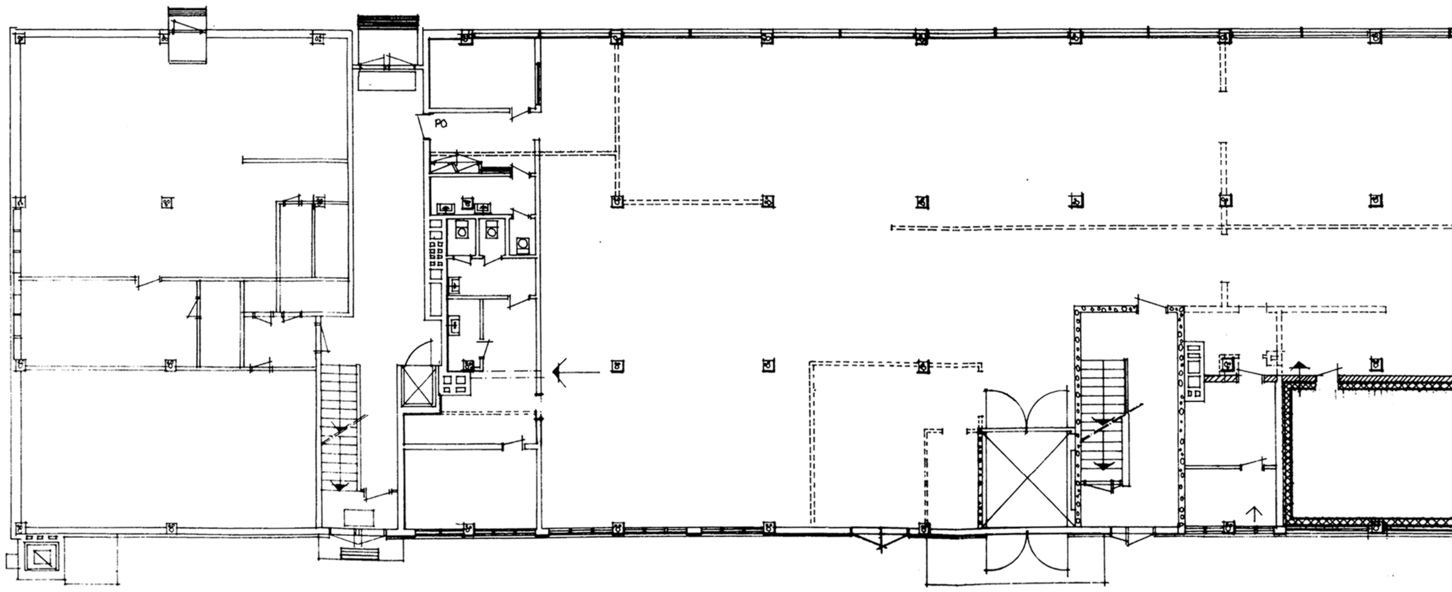


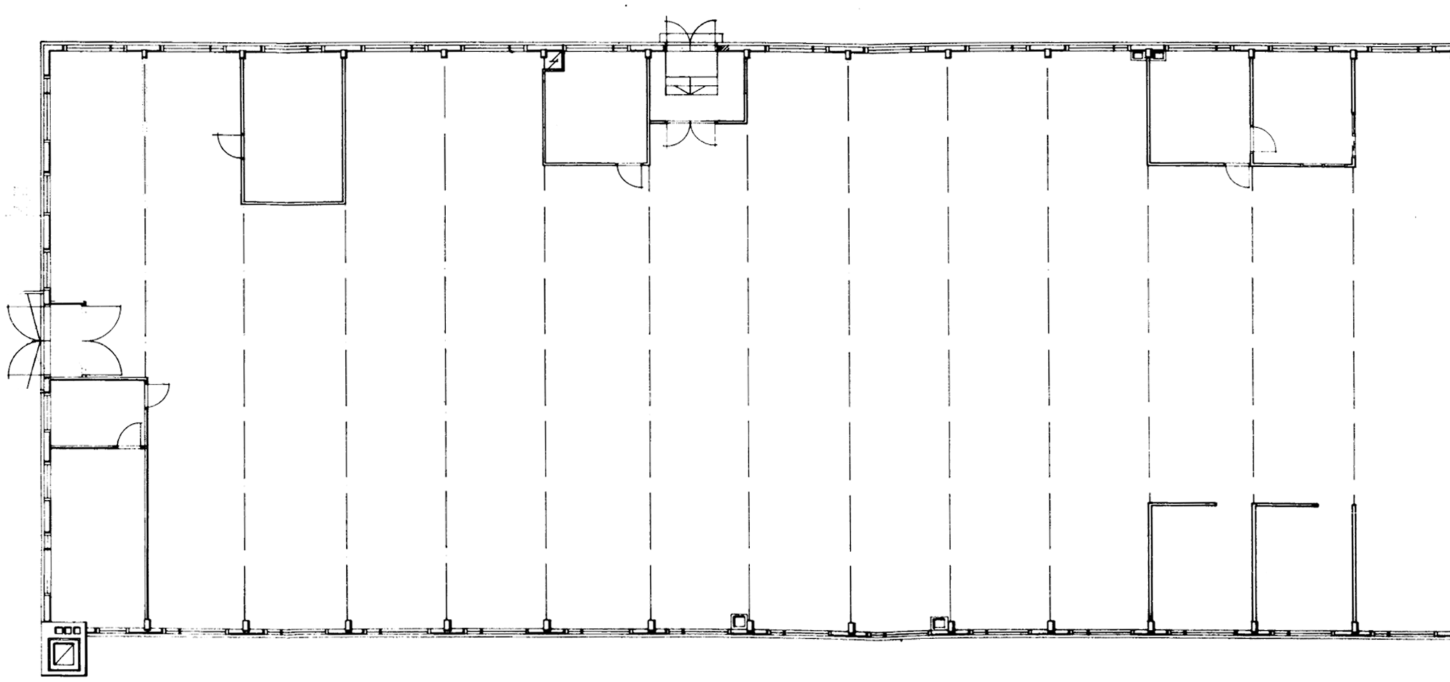


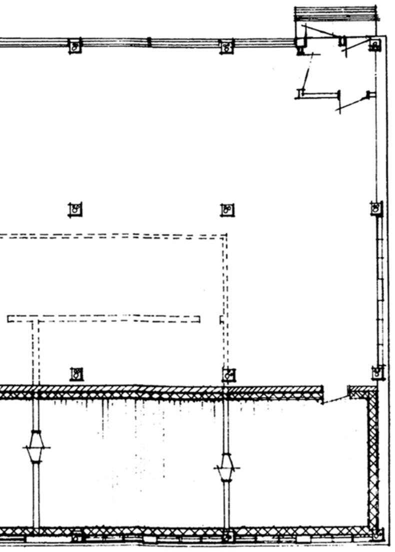
scale | 1:250

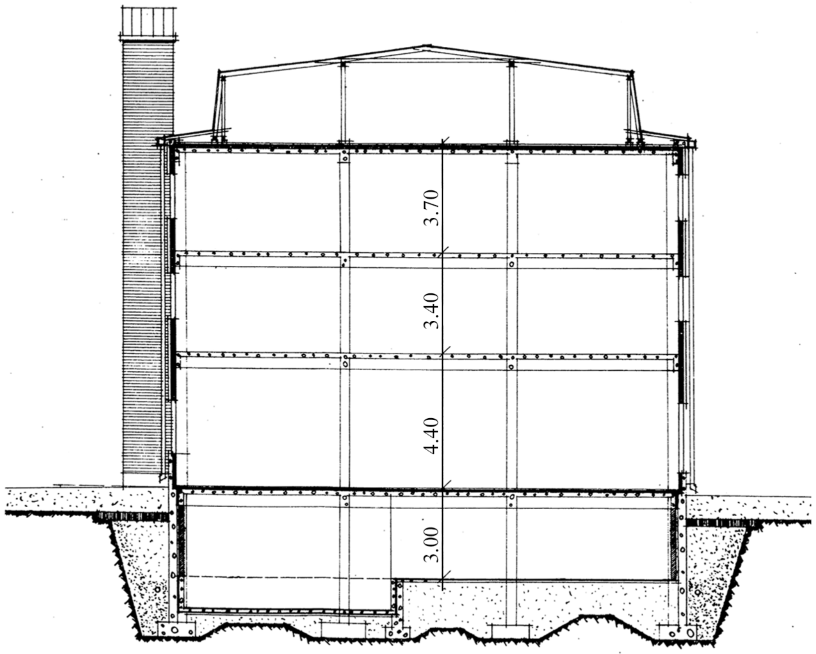
Kaleva, Tampere Demolished Buildings





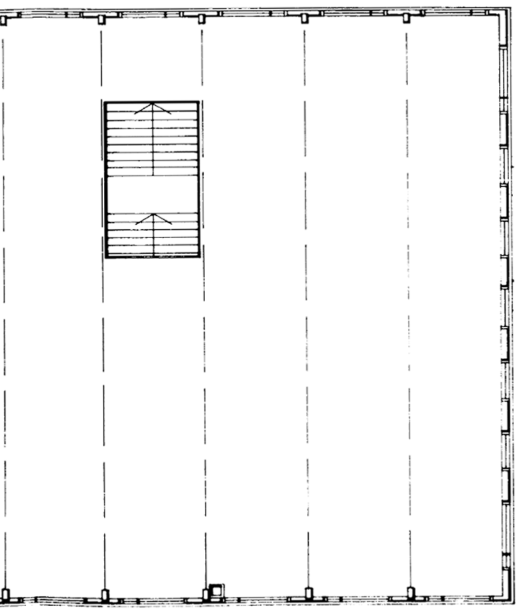




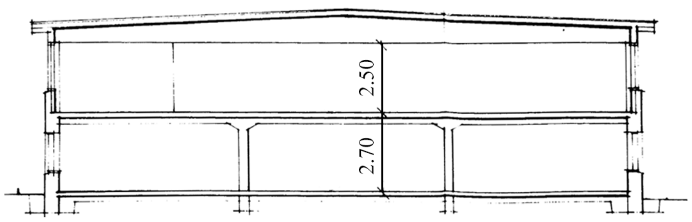


scale | 1:250

Building 4 used to be an office building, the ground floor was mainly used for commercial functions such as shops, cafés and restaurants. The buildings was erected in 1963 and had a gross floor area of 1 408 sqm. The concrete post and beam structure was demolished in 2015, after 52 years of service.
Instead of demolition, the building would have had ideal spatial properties for a residential building. Decent room heights and a building depth of max. 12 metres would have been suitable for living spaces. The structure might have even allowed the extension by one to two extra floors.



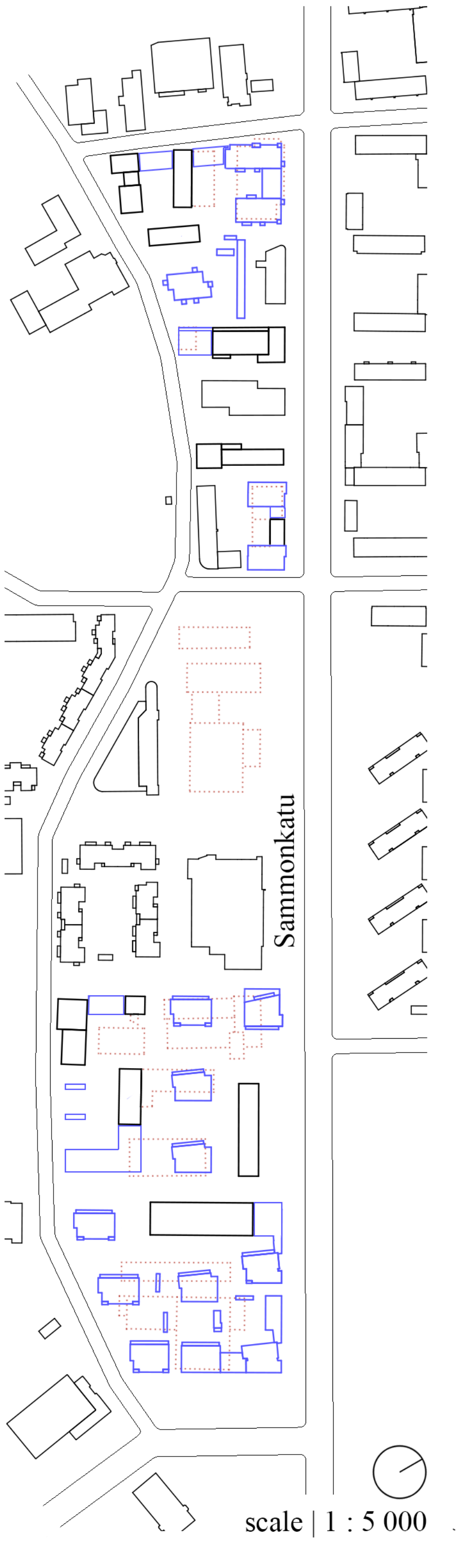
Building 5 was used by a car dealer. The concrete post and beam structure was built in 1969. I had a building depth of around 20 metres and length of almost 70 metres and accumulated to 2 780 sqm of gross floor area. The building was demolished in 2014 to make way for large residential buildings.



scale | 1:250

Instead of demolition, the structure could have been reused as a commercial & office building. Higher room depths would have made it difficult to use it as a residential buidlings. Another alternative use for it would have been as a garage building which would have saved the construction of several car ports in the area. It could have also been used as storage building for the surround residential buildings which would have allowed to save those functions from the newly built residential structures.

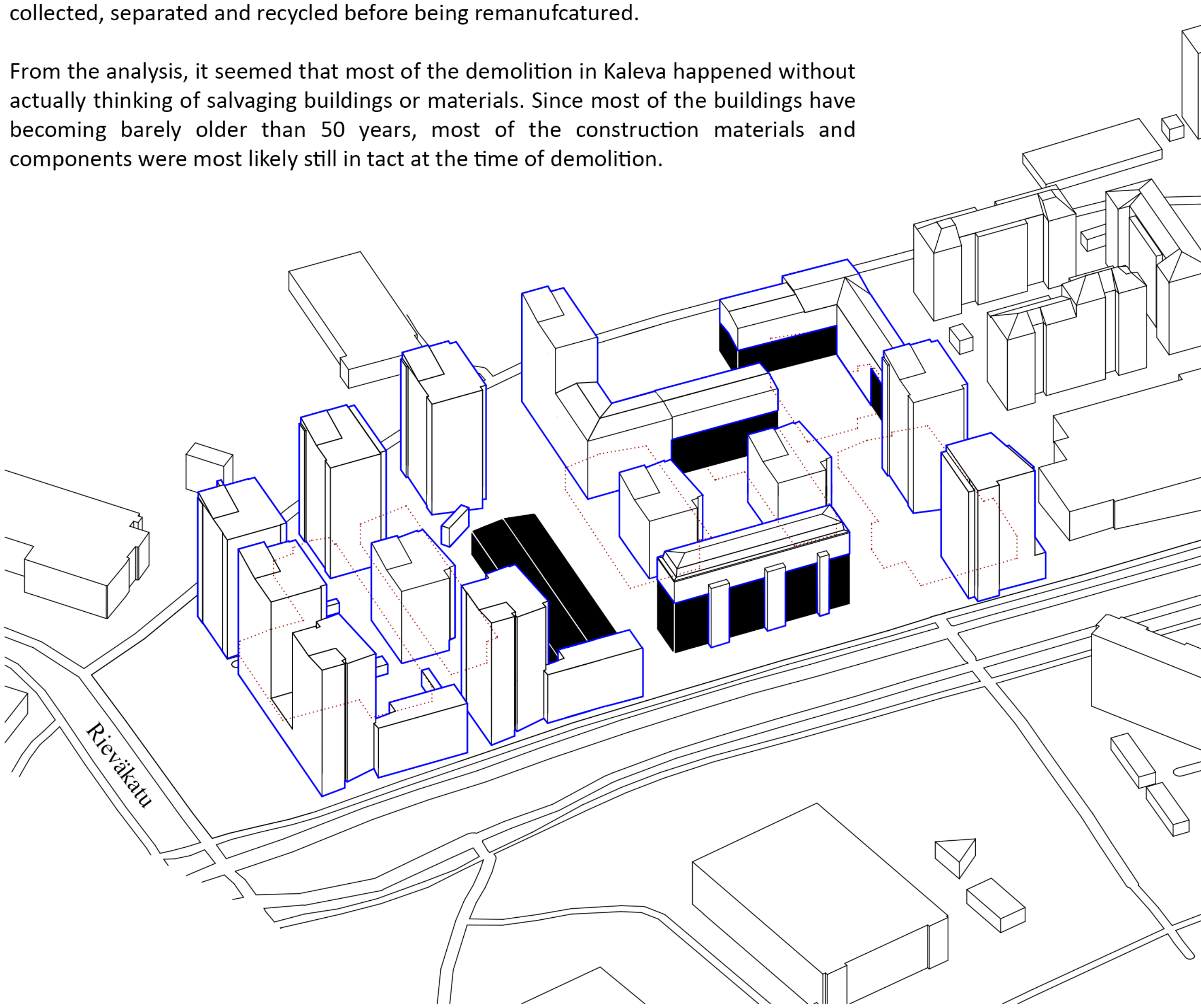
Kaleva, Tampere the Alternative Plan

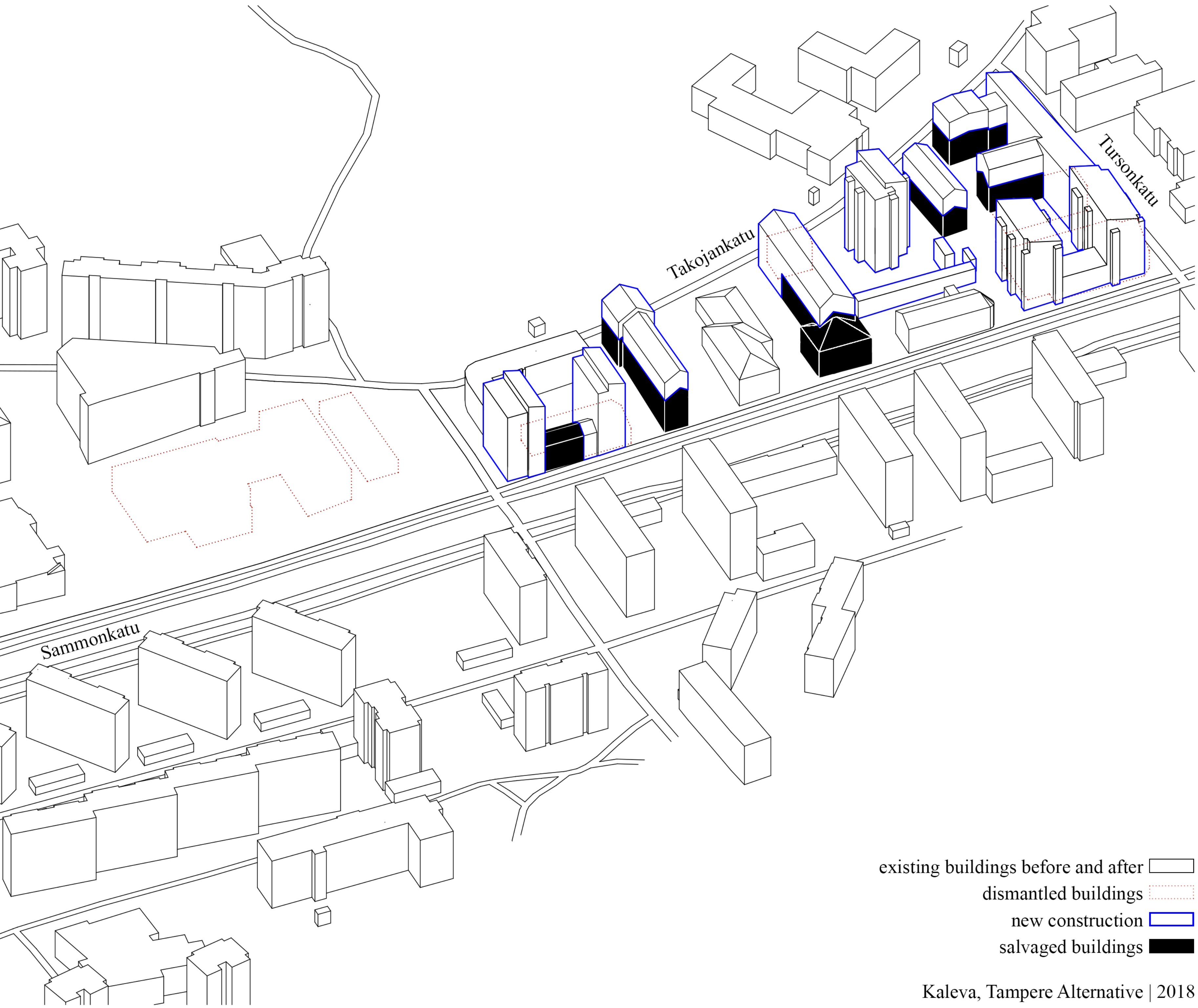


Through an analysis of the demolished buildings, it was found out that many of them happen to have adequate spatial properties to be transformed into e.g. residential buildings. Buildings that had this kind of transformation potential were kept and marked in the map in dark black. Those buildings were each extended by adding two extra floors out of a light-weight structure.

The remaining buildings were marked to get dismantled. Some of them have a high level of prefabricated building components that could have been reused for the construction of new buildings. The materials of other buildings could have been collected, separated and recycled before being remanufcatured.

From the analysis, it seemed that most of the demolition in Kaleva happened without actually thinking of salvaging buildings or materials. Since most of the buildings have becoming barely older than 50 years, most of the construction materials and components were most likely still in tact at the time of demolition.





Kaleva, Tampere Alternative | 2018

7

CONCLUSION

Between 2000 and 2018, Tampere's building stock has experienced significant growth. Almost one quarter of the existing building gross floor area in 2018 was built after 2000. Especially the housing sector grew, 65% of total new construction after 2000 were either blocks of flats, detached or row houses. New buildings were commonly larger and built with very carbon intensive construction materials such as concrete or steel. The rapid transformation towards more, larger and more carbon intensive buildings raises the question how such construction behavior is line with Tampere's ambitious goals of becoming carbon neutral.

More than 75% of total demolished floor area happened after an average life span of only 37 years. Most of these buildings were made of concrete which reflects the average age of the cement-based construction material of only 36 years. Demolition behavior in Tampere has been too thoughtless, not only because of high embodied energy that goes to waste after an unacceptably low material life span, but also because parts of city's built heritage in form of brick buildings were demolished without thinking of its loss of a local identity.

Against the assumption that building obsolescence is highly influenced by the conditions of the building products, the study at hand has shown that the lifespan of materials and construction techniques have little to no influence on demolition. In fact, it is often smaller buildings that were replaced by larger ones of the same type. Especially larger commercial & office buildings and blocks of flats replaced smaller buildings. While changing spatial requirements are one major driver for demolition, changing land use is another one. Often, industrial buildings, warehouses and commercial & office buildings were demolished to make way for the new construction of blocks of flats.

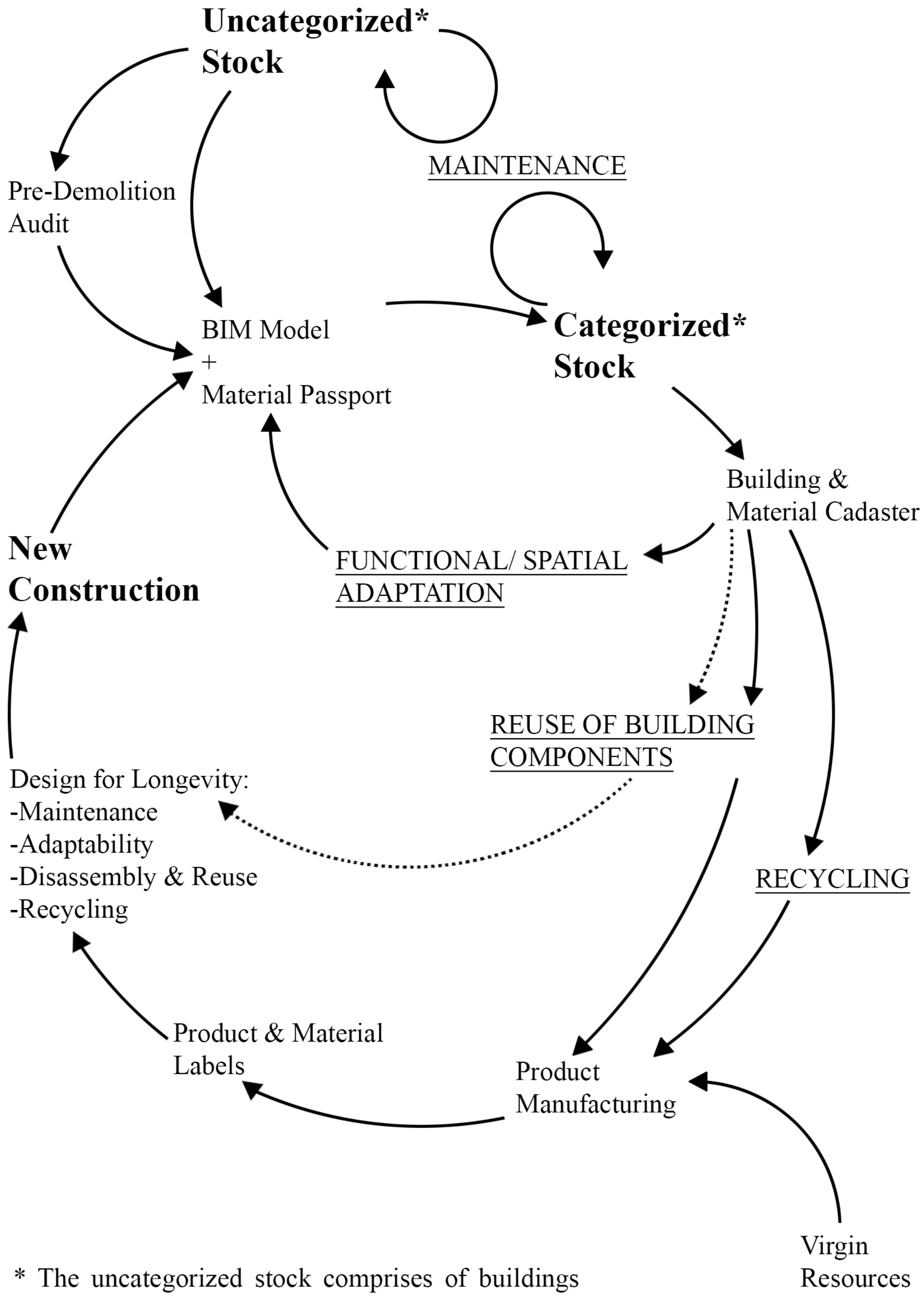
High emissions caused by new construction of buildings requires a shift towards a more circular approach of construction and demolition behavior. The overarching goal of a circular economy is to treat buildings, their materials and construction products as if they were resources for future construction. So, after they have reached their end of life, they will be reused instead of getting disposed. In a fully functioning circular economy, there is no such thing as (demolition) waste.

Building maintenance, one of the most crucial factors in a circular economy, does not only concern users or owners, the design of construction products and buildings have a high influence on how well they can be maintained. The replacement of buildings has had the largest impact on Tampere's building stock. In order to avoid buildings getting demolished because their functional or spatial properties have become unsuitable, there is a chance to transform them through spatial extension (or reduction) or functional adaptation. The adaptability of buildings highly depends on its structural and spatial layout and therefore addresses especially building designers. Nevertheless, buildings that have not specifically been designed for transformation often have a natural potential for adaptation. In Tampere, especially smaller commercially used buildings might have such potential to be reused for e.g. residential purposes, while the loadbearing structures of existing buildings often allows an extension of up to two additional floors made of a lightweight structure. In case buildings can't be preserved as such, their components could potentially be reused for future new construction. In Tampere, there is a large stock of blocks of flats which are often made of a similar construction technique. Components of those buildings could potentially be harvested and reused for new construction. The reuse of building components highly depends on their design, their measures, physical attributes and joint techniques. The recycling of building materials is the least favorable stage in which the harvest and remanufacturing of products consumes a vast amount of energy.

In order to activate the circular potential of Tampere's built environment, information about buildings, their components and materials need to be made accessible. The lack of knowledge complicates the circular treatment of buildings significantly. Therefore, a building material cadaster becomes a valuable instrument which links the building stock to owners, designers, developers, planners, manufacturers and builders, including demolition (or rather disassembly) companies. The information of new buildings will be fed through BIM models and Material Passports into the cadaster. The stock of buildings. for which information is not yet available, will have to go through Pre-Demolition Audits before they are chosen to be brought down.

The work has shown that Tampere is several steps away from a circular built environment. The shift away from wasteful demolition practices will generally require rethinking in how buildings and their materials are treated. Demolition will have to make way for more sustainable solutions that accurately address a problem at hand. Demolition will have to become unattractive for everyone involved while the reuse of buildings, components and recycling of materials need to become more attractive.

All that requires systematic change. Penalty taxes on demolition and financial benefits for building adaptation might encourage a rather resource-saving approach. Profitable testing procedures and material labels need to be developed in order to gain financial benefit from reuse. The demolition and construction industry must be aided in their transformation. But above all, humankind needs to understand its position in world that is driven by circular processes.



* The uncategorized stock comprises of buildings that are built before the use of BIM models and Material Passports become mandatory. Those buildings become categorized stock either through Pre-Demolition Audits or by categorizing them post construction.

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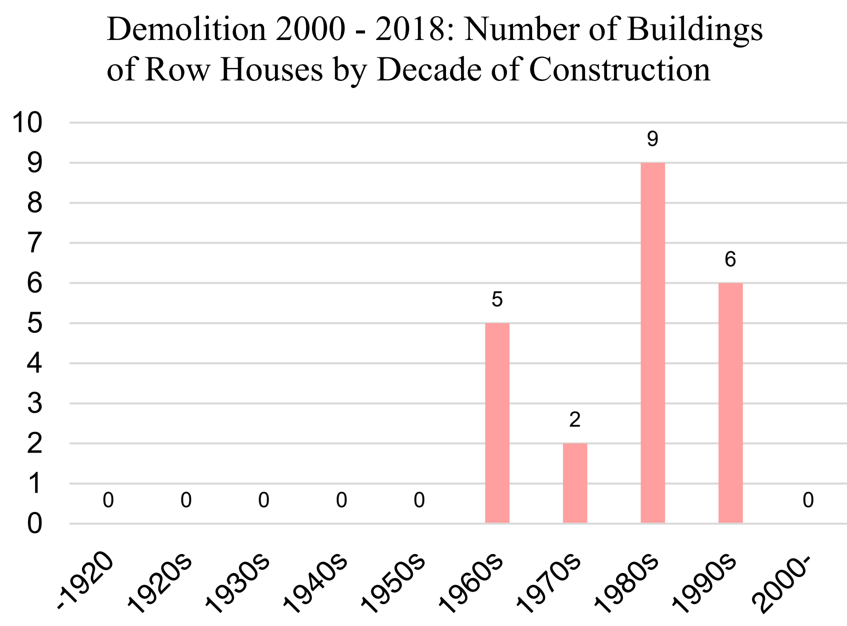
Appendix

Data Processing

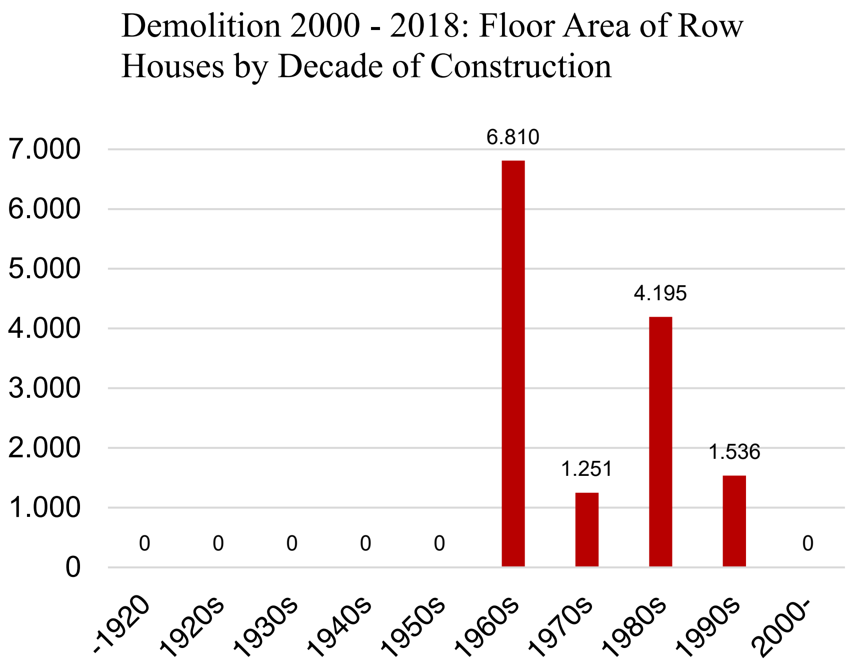
For the studied period, the BDR contained 2841 and the local data 4758 records for demolished buildings or structures in total. In total, the amount of records in the BDR is only 60% of that in the local data. To get most out of both data sets, a merger was performed for which the local one was determined as the starting point as it has information on the building's location and the BDR has not. For this purpose, the local data set was looked through manually in order to find those records which appear to have reliable data. This process resulted in a selection of 2 017 out of 4 758 that were merged with the BDR. Through this merger, missing information for year of construction, floor area and construction material have been added. The remaining 2 741 records were then matched with the BDR by their building ID which resulted in 109 reliable records that were added to the data set. Another merger by lot ID and impermanent building number was performed and, after a manual check, resulted in 915 matches could be added to the data set. The remaining 1 717 records from the local data were then merged by lot ID which bears a high chance for errors as there can be several records on a single lot. Therefore, these records had to be checked manually and eventually, 107 records were found to be reliable. After eliminating 14 errors, the final number of records is 3 134. Of these, 1 954 lacked information on the floor area, which was compensated by creating an average from the corresponding building type.

Similar difficulties as for demolished buildings occurred for the data sets of the existing ones. The local data contains 49 262 records and the national data set can be searched for existing buildings in two different ways: first, by extracting "not demolished" buildings according to the state of usage and second, by separating "ready buildings" by building conditions. The first method led to 37 627 results, the latter provided 43 584 records. After a direct comparison of these results, a decision was made to look more closely into each building type individually which method to use. For residential buildings (detached houses, attached houses and blocks of flats), holiday cottages, dormitories, commercial and office buildings, public buildings and warehouses it was decided to use "ready buildings" of the local data for further processing. For industrial buildings a more through comparison was made. Out of 1 196 records for industrial buildings in the local data and 960 records in the national data set, 839 could be merged based on the lot ID. Approximately 180 of these matches either contained varying information or one of the datasets lacked information on one or several of the categories. Since most of these data gaps appear in the local dataset, the decision was made in favour of the national data set. Finally, the credibility of the remaining 357 records of the local data set was examined after which 53 additional records were chosen to be added. This process resulted in 1 013 records in total. For the remaining building types (agricultural, transport, utility and other buildings) it was concluded that the best results would be achieved by using again "ready buildings" of the local data set. Eventually a total number of 43637 records of existing buildings was used for the purpose of this study.

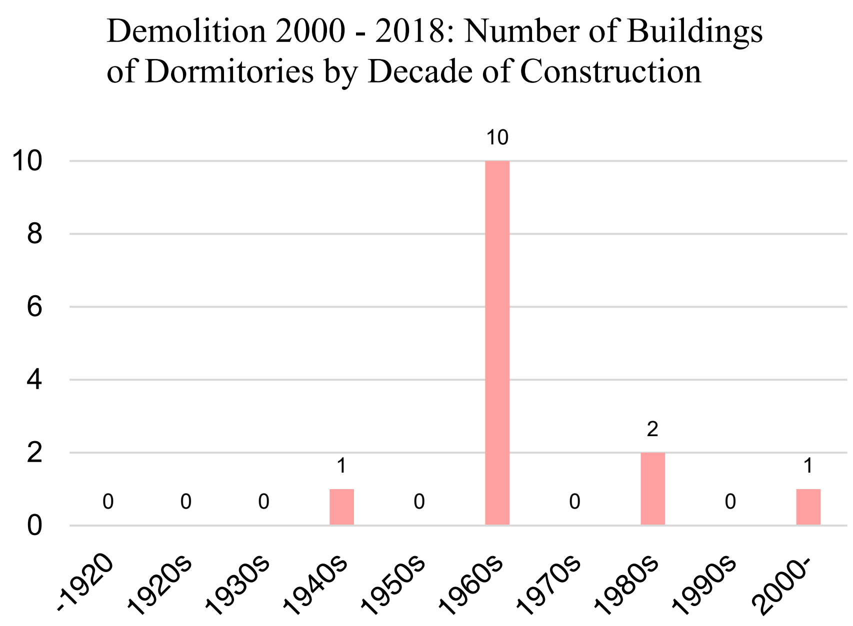
4.2 Demolition



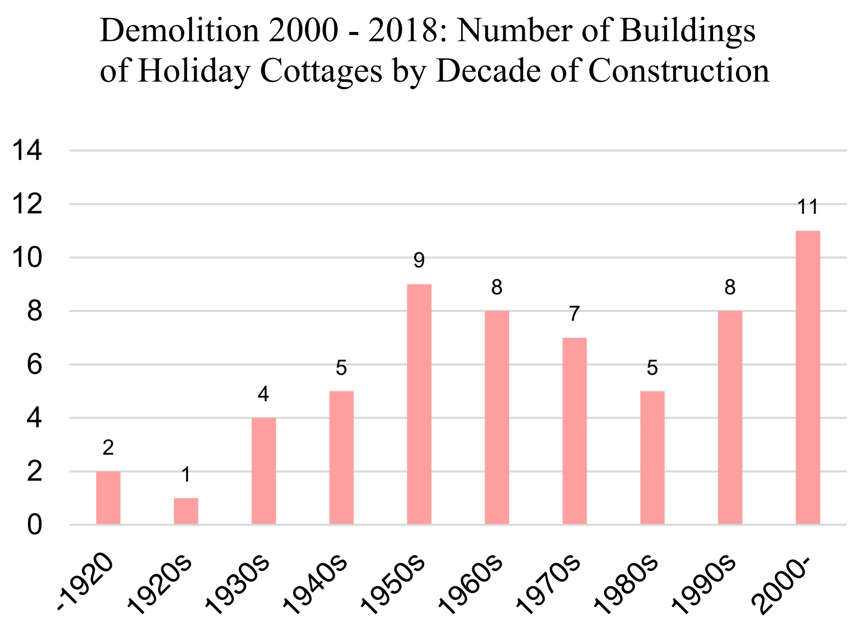
Graph: Numbers of demolished row houses by decade of construction



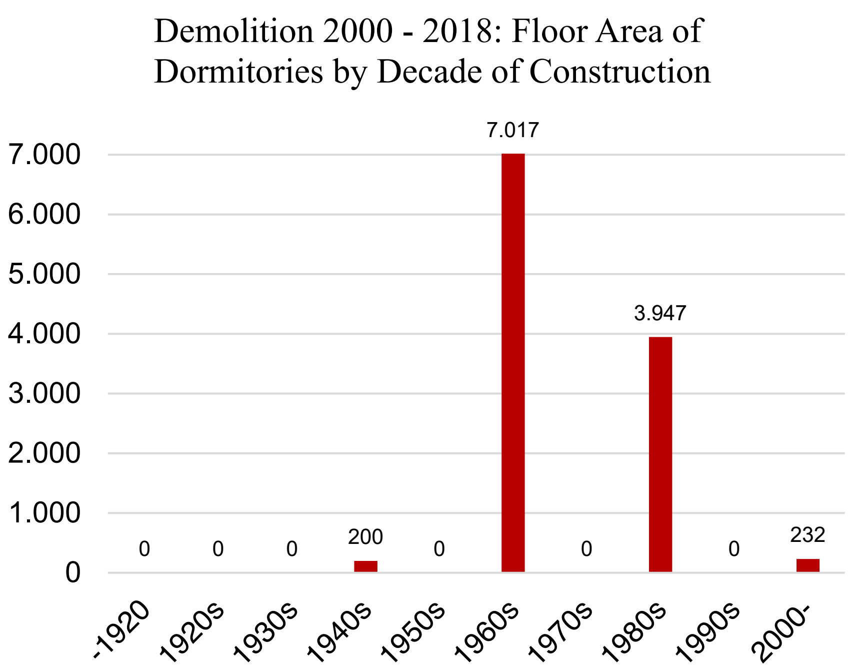
Graph: Floor area of demolished row houses by decade of construction



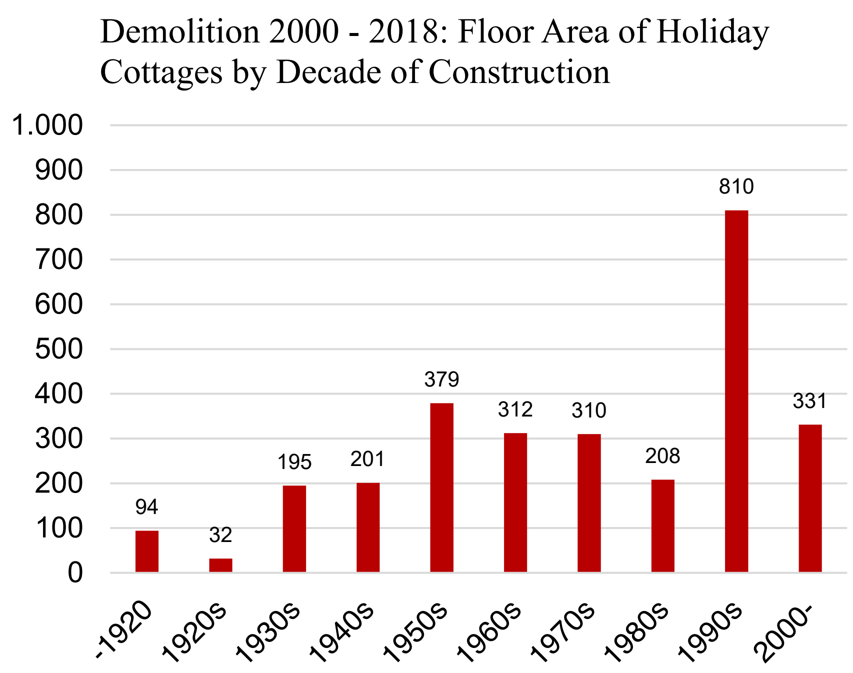
Graph: Numbers of demolished dormitories by decade of construction



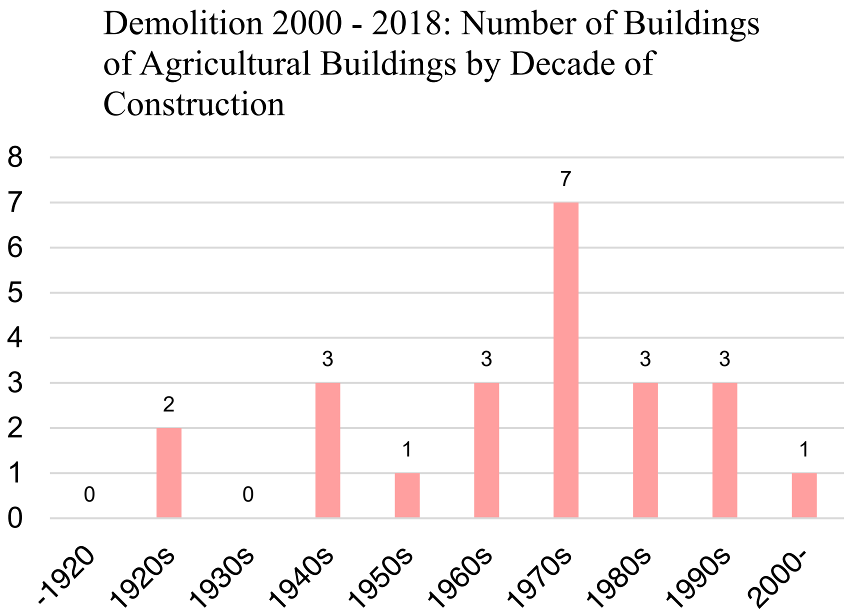
Graph: Numbers of demolished holiday cottages by decade of construction



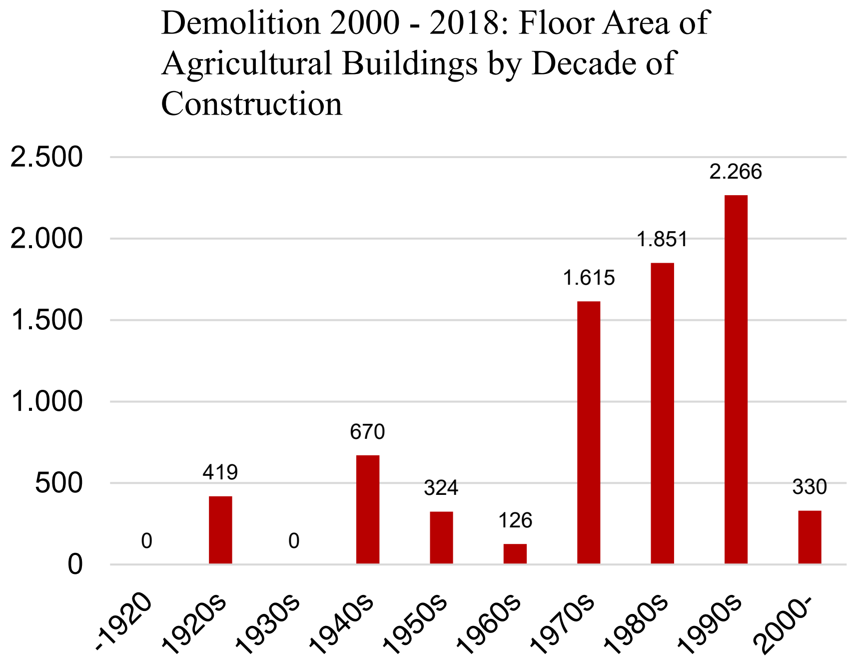
Graph: Floor area of demolished dormitories by decade of construction



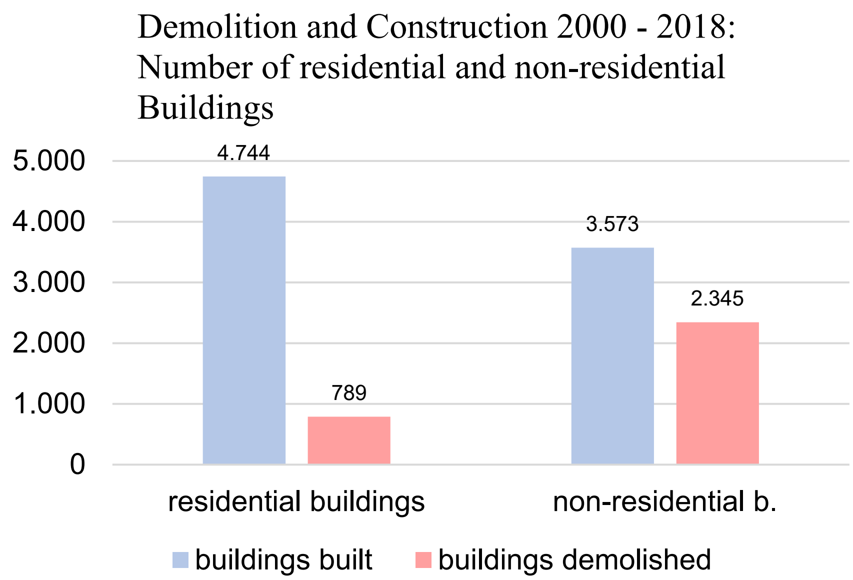
Graph: Floor area of demolished holiday cottages by decade of construction



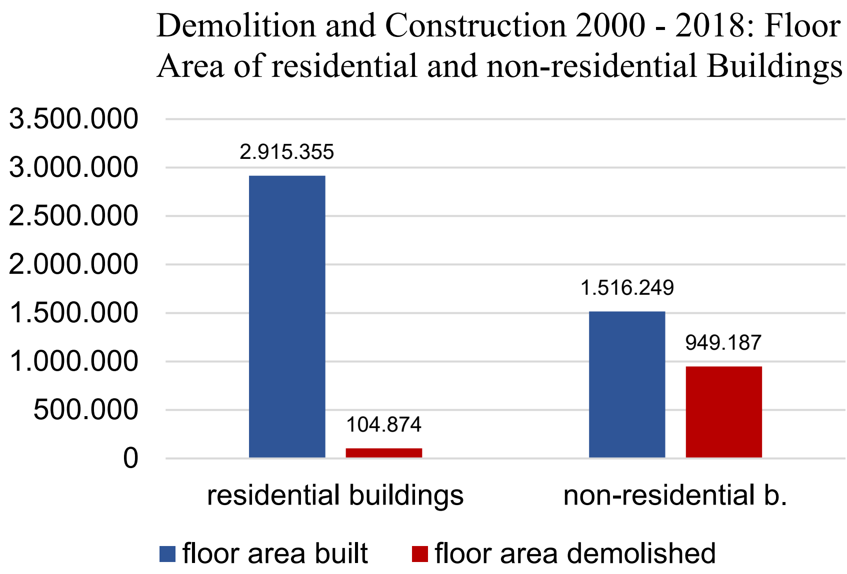
Graph: Numbers of demolished agricultural buildings by decade of construction



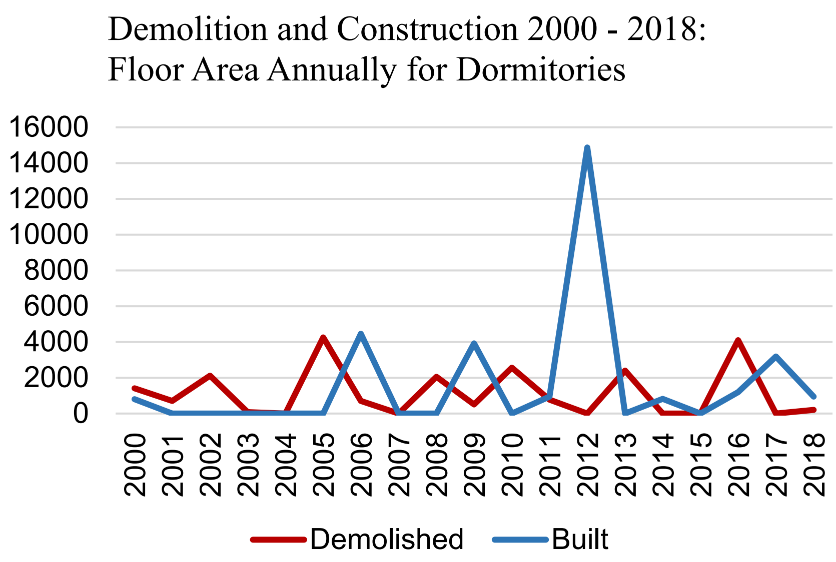
Graph: Numbers of demolished agricultural buildings by decade of construction



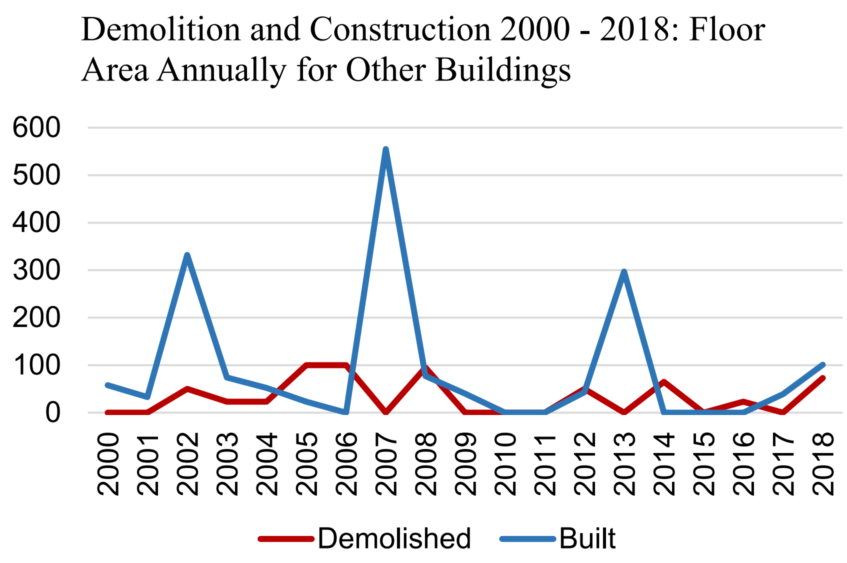
Graph: Numbers of buildings demolished and built, residential and non-residential buildings



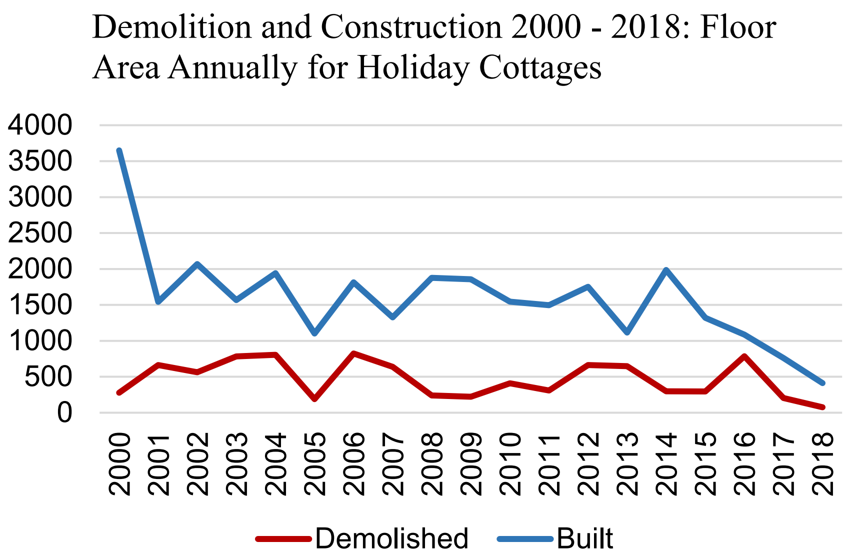
Graph: Gross floor area of buildings demolished and built, residential and non-residential buildings



Graph: Demolished and built gross floor area annually for dormitories

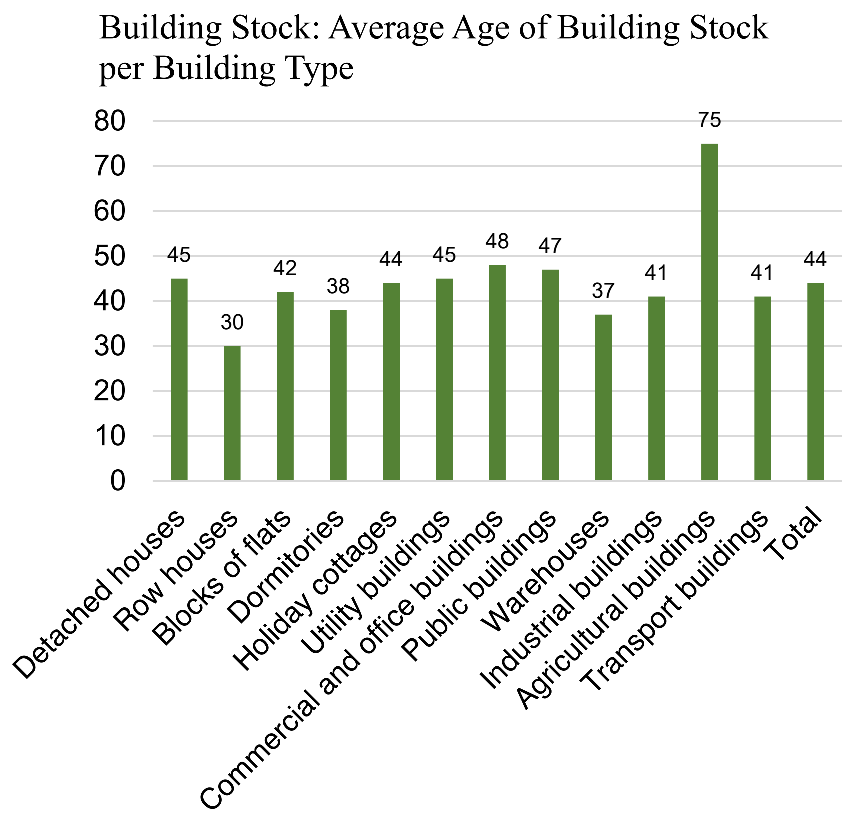


Graph: Demolished and built gross floor area annually for other buildings

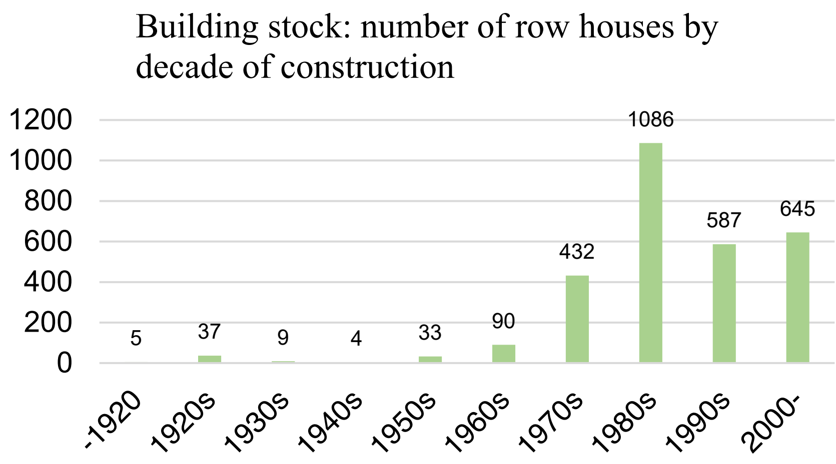


Graph: Demolished and built gross floor area annually for holiday cottages

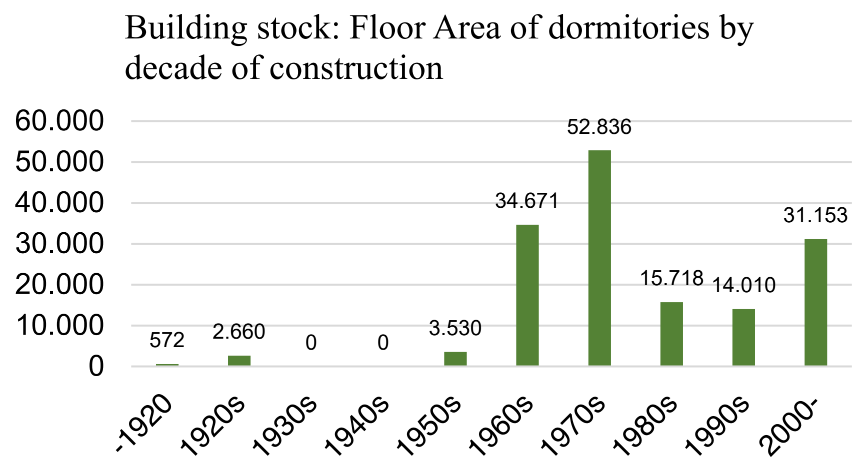
4.4 Building Stock



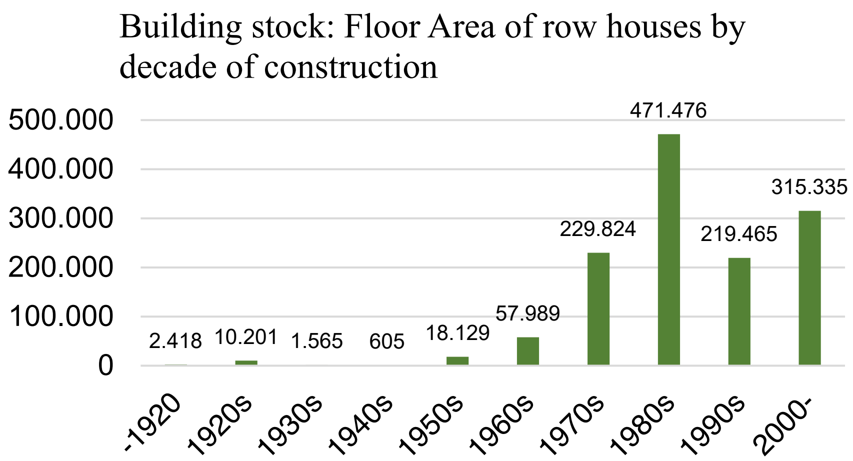
Graph: Average age of existing buildings by building type



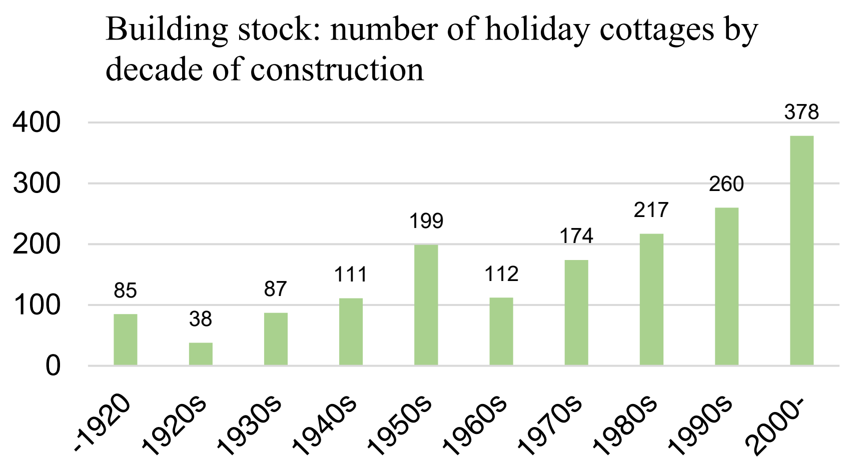
Graph: Numbers of existing row houses by decade of construction



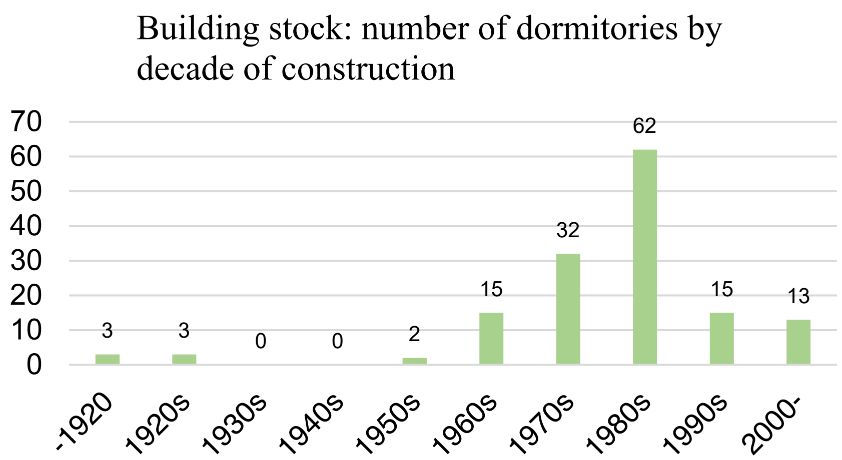
Graph: Gross floor area of existing dormitories by decade of construction



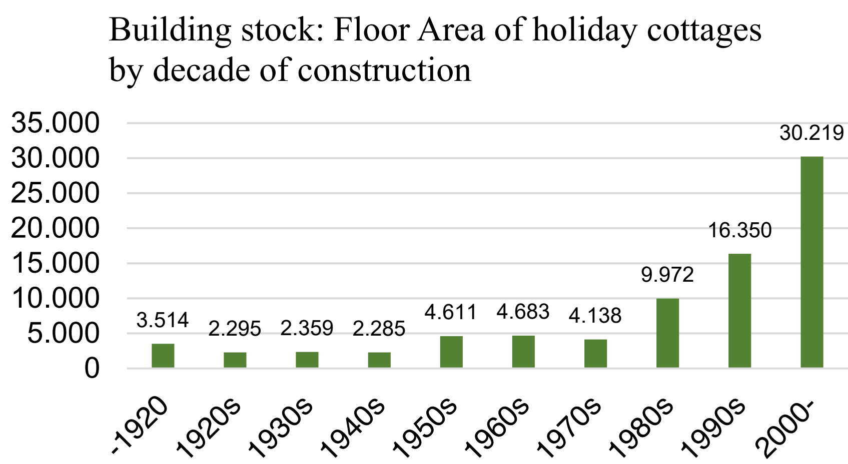
Graph: Gross floor area of existing row houses by decade of construction



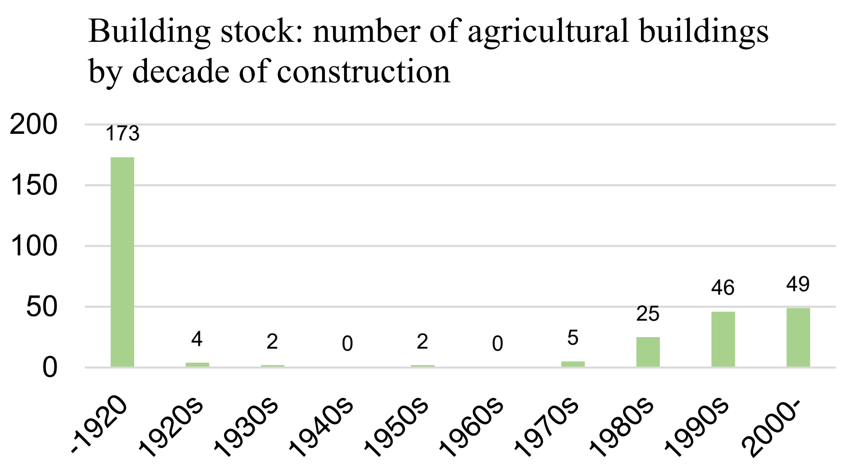
Graph: Numbers of existing holiday cottages by decade of construction



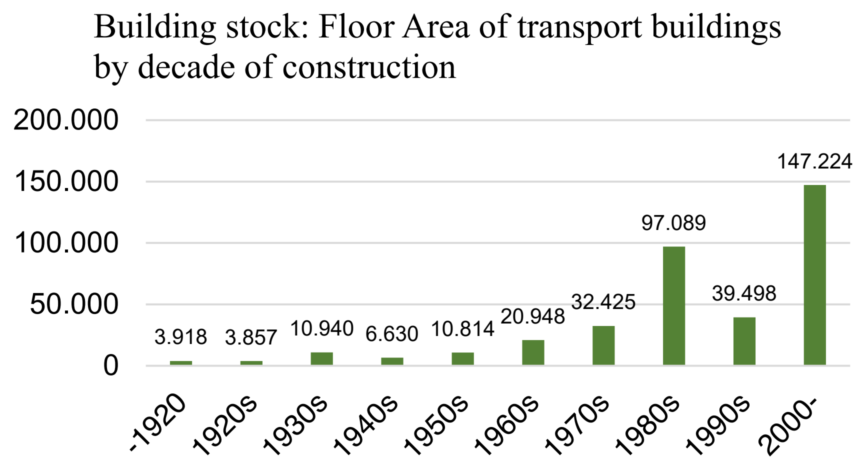
Graph: Numbers of existing dormitories by decade of construction



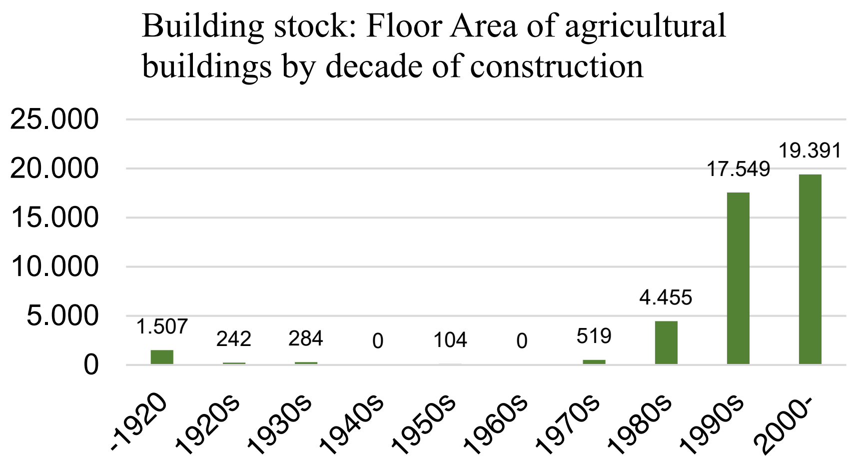
Graph: Gross floor area of existing holiday cottages by decade of construction



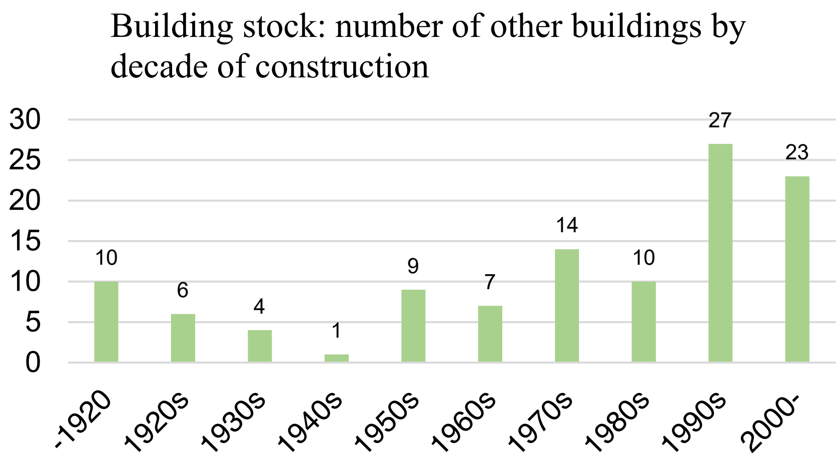
Graph: Numbers of existing agricultural buildings by decade of construction



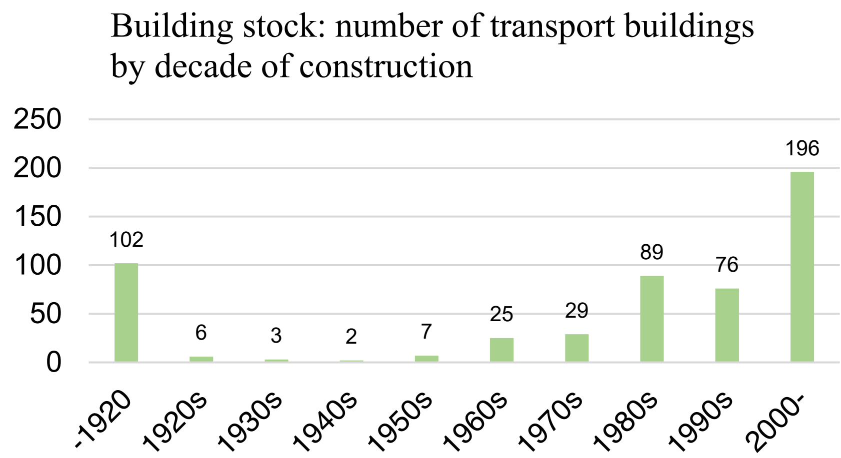
Graph: Gross floor area of existing transport buildings by decade of construction



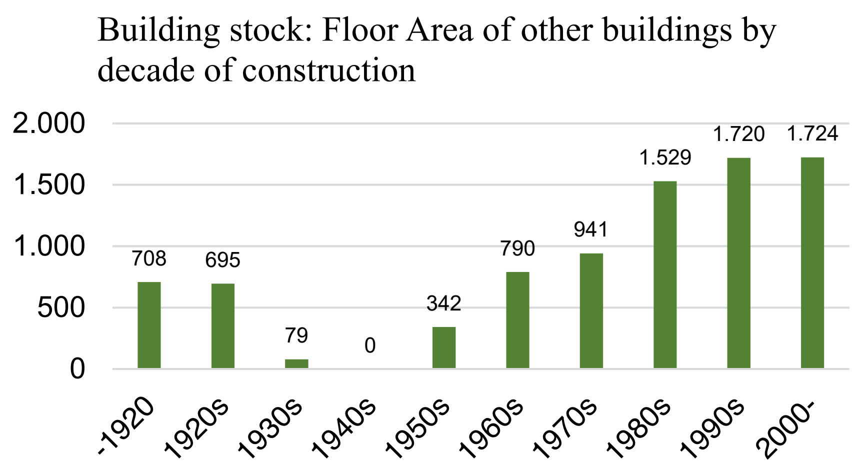
Graph: Gross floor area of existing agricultural buildings by decade of construction



Graph: Numbers of existing other buildings by decade of construction



Graph: Numbers of existing transport buildings by decade of construction



Graph: Gross floor area of existing other buildings by decade of construction