Chapter

Wooden Extra Stories in Concrete Block of Flats in Finland as an Ecologically Sensitive Engineering Solution

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Abstract

This chapter examined the various stages and benefits of wooden extra stories from the perspective of Finnish housing and real estate companies through interviews with professionals involved in these projects. Key findings highlighted are as follows: (1) in the feasibility study, project planning primarily focuses on property condition and potential improvement targets as well as other considerations, for example, compliance with current regulations and parking arrangements; (2) in the project planning, application of extra stories is thoroughly examined, and construction costs, profits, and the sale of building rights are discussed; (3) in implementation planning, issues related to building rights, city plan change, and conditions of the company that manages the property play an important role; and (4) during construction, frequent information updates are made to residents regarding the site arrangements and the construction program. Wooden extra floor construction, which requires commitment, investment, and cooperation among the interested parties, has great potential in construction technology, contracting mechanisms, and ecological engineering solutions. It is believed that this chapter will increase the dissemination of wooden extra stories, thus contributing to the greater use of more sustainable materials in renovation projects and the ecologically sensitive engineering approaches to meet the challenges arising from climate change.

Keywords: timber/wood, wooden extra story, ecological engineering solutions, sustainable material, sustainability, building construction

1. Introduction

Climate change has reached a critical level [1, 2]. The probability of attributing global climate change to human factors is 95% and the risk of anthropogenic climate change requires the management of our operations [3]. In this sense, around 40% of the EU's total energy consumption and more than 35% of energy-related greenhouse gas emissions come from buildings [4]. The role of buildings, especially houses, in our lives during the COVID-19 crisis is more critical and the home has become the focal point of the daily life of millions of people in the EU, as more people started working from home. For example, some evidence-based surveys showed a large increase in the share of workers working from home compared to pre-crisis figures; from 30% in Canada to 70% in South Africa [5].

Especially at this point, renovation can turn crisis into opportunities to make our residential buildings suitable for a greener and digital society and to sustain economic recovery. To achieve 55% emission reductions in the 2030 climate target plan, the EU must reduce the greenhouse effect of buildings by 60% gas emissions, final energy consumption by 14%, and energy consumption for heating and cooling by 18% [6]. Moreover, emissions during building construction accounted for a total of 7% of Finland's greenhouse gas emissions in 2018, and emissions from the use of buildings account for 23% of the total [7]. Therefore, a focus on renovating the existing building stock to make it more energy-efficient and less carbon-intensive becomes urgent as an issue of ecological engineering in the context of circular economy and sustainable development [8, 9].

As in many European countries, Finland's building stock was mostly constructed before the 1990s, and this energy-poor stock often needs refurbishment to meet new building standards [10, 11]. This old stock, especially residential buildings built in the 1960s and 1980s (**Figure 1**), requires major renovations to approach a sustainable and carbon-neutral built environment [12, 13]. The renewal of building codes in Finland in recent years has contributed to accelerating the above transformation by aiming to make new construction methods increasingly more ecologically sound, sustainable, and at the same time more energy-efficient [14, 15].

Housing and real estate companies play an important role in building renovation that makes older buildings more sustainable, ecological, and energy-efficient [16]. The issue becomes even more important when it is considered that there are over 60,000 flats in Finland, where nearly half of the Finnish population lives [11]. Renovating an apartment by increasing accessibility and energy efficiency is a slow and costly process, requires a lot of capital and government subsidies, and the intensity of fieldwork distracts building occupants and residents living near the construction site [17–20].

In this context, extra story construction (**Figure 2**), which is advantageous in many aspects such as financial, environmental, and energy efficiency, stands out as a viable solution. It can cover the costs of property development and renovation to finance the necessary measures, directly increase the energy efficiency and indirectly support the energy renovation using the revenues from it, and finance the

Figure 1.
A residential complex in Finland built in the 1960s (source: Wikipedia/Tiia Monto).

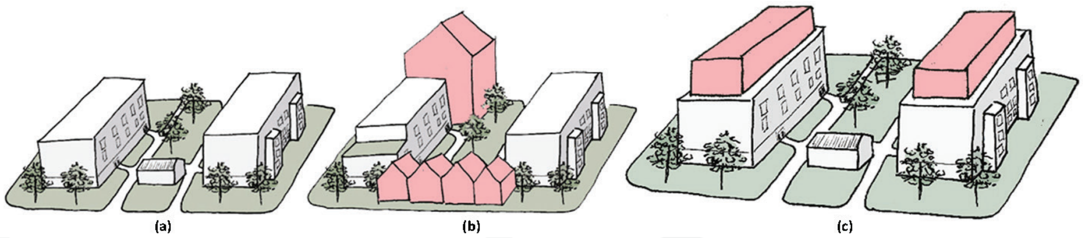

Figure 2.
Additional (story) construction: (a) basic; (b) additional construction; and (c) extra story construction.

construction of a retrofit elevator or new/extended balconies, thereby increasing the sustainability and living comfort [21–23].

Reinforced concrete-framed apartments built in Finland between the 1960s and 1980s allow the construction of extra stories, often using lightweight structures. Since these structures have flat roofs, they make it easier to add floors architecturally and technically. In addition, Finland's current fire regulations enable lightweight extra stories from materials such as wood [24].

The materials used in renovation should be renewable, recyclable, and long-lasting and their production should be sustainable and ecologically sound in nature, consuming minimum energy and producing as few emissions as possible as an ecological engineering solution [25, 26]. In this sense, timber is one of our best partners in tackling the climate crisis due to its potential eco-friendly properties, for example low-carbon emissions, and is at the forefront of addressing European climate policy [27–33]. Moreover, wood offers light prefabricated alternatives to meet the special design needs with its wide thermal insulation and size options [34, 35].

The reform of the legislation on building and construction also prepares for a transition toward low-carbon building. In the future, carbon reduction must be taken into account in the whole life cycle of a building, that is in new buildings and renovation and demolition [36]. In this case, extra story construction stands out as a sustainable and practical alternative.

To date, no study in the literature provides a comprehensive understanding of this sustainable approach, especially in housing facilities. In this chapter, the various phases, advantages, and disadvantages of the wooden extra story are examined from the perspective of housing and real estate companies by interviews. These interviews underlined the main points in the four stages of extra story construction—(1) feasibility study; (2) project planning; (3) implementation planning; and (4) construction.

It is worth noting here that as a recently matured discipline, ecological engineering or ecotechnology is a combination of applied ecology, environmental engineering, biotechnology, systems control, and complexity sciences and has a wide range of applications such as conservation and restoration of natural habitats [37, 38]. Ecological engineering has become an important tool, especially today, with the use of sustainable materials to tackle climate change challenges. Considering that more than one-third of energy-related greenhouse gas emissions originate from buildings, renovation of buildings with wooden extra stories will make a significant contribution to combating the climate crisis in the context of ecological engineering.

In this chapter, wood and timber refer to engineered wood products such as cross-laminated timber [(CLT) a prefabricated multi-layer EWP, manufactured from at least three layers of boards by gluing their surfaces together with an adhesive under pressure], laminated veneer lumber [(LVL) made by bonding together thin vertical softwood veneers with their grain parallel to the longitudinal axis of the section, under heat and pressure)], and glue-laminated timber (glulam) [(GL) made by gluing together several graded timber laminations with their grain parallel to the longitudinal axis of the section)].

2. Literature survey: wooden extra story construction

The terms extra floor, roof, or elevation are used when the roof shape of the building changes, the height increases, and the number of floors of the buildings increases. As in many examples in Finland (**Figure 3**), one of the effective ways to improve the property is to change the use of buildings (**Figure 4**) as well as to construct extra floors [39]. Moreover, extra stories are currently being built by using modern construction methods with lightweight prefabricated elements, and buildings constructed in Finland in the 1960s and 1980s can usually support one or two extra stories [40].

Extra story construction has many benefits such as [41]—(i) from an environmental point of view, as an ecologically sensitive engineering solution, renovation and improvement operations with extra stories were more than 20% lower in carbon footprint compared to demolition and new construction [39], thus it increases the income of the property owners, resulting in a beneficial development of the building stock; (ii) from a financial standpoint, its revenues can be used to finance the renovation of existing property, such as the renovation of an elevator (**Figure 5**), to improve the

Figure 3.
Extra story construction examples from Finland.

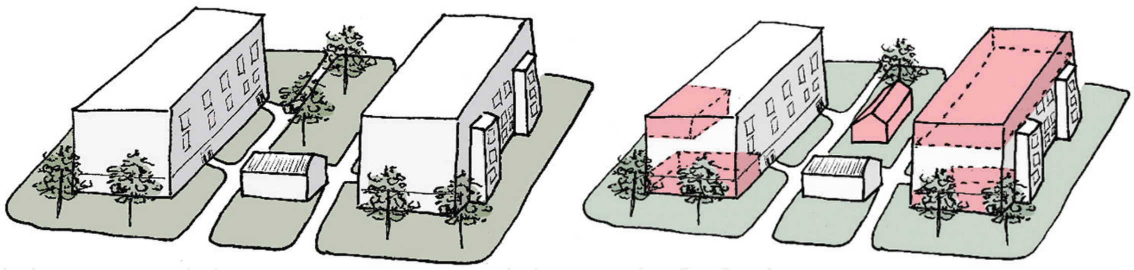

Figure 4.
Roof and ground floor renovations and building usage changes to increase efficiency. The building's internal storage facilities have been moved to a new outbuilding.

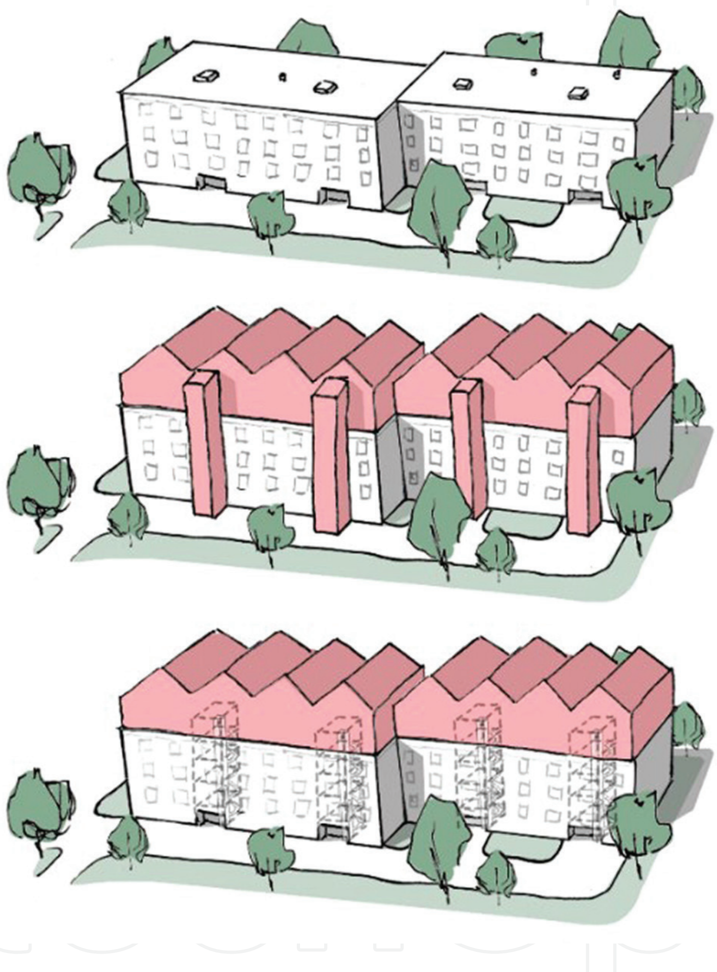

Figure 5.
A retrofit elevator can affect the architectural appearance of the building as well as accessibility.

building's accessibility and commercial conditions; (iii) in terms of energy efficiency, extra story construction does not significantly increase the overall energy consumption of the building, although it significantly increase the total floor area and as passive energy efficient structures, it can significantly improve the energy efficiency of old buildings, especially if the upper floors have not been renovated for a long time; (iv) from esthetical point of view, it can significantly affect the architectural features of the building and improve the facade appearance; and (v) from a social (sustainability) point of view, that is understanding people's needs and desires (e.g., [42, 43]), extra story construction that meets the demands of residents, where Finnish suburban residents generally have a positive attitude toward this sustainable solution [44].

On the other hand, according to some studies in the literature (e.g., [45–47]), the lack of cost-competitiveness of wood compared to conventional materials such as steel and concrete can be considered a disadvantage of wood in the construction of extra stories.

The materials used in renovations should be renewable, recyclable, and long-lasting and their production should consume only a minimum amount of energy and produce as few emissions as possible to ensure the sustainable ecology of the business [48]. Studies indicate that wood-based products are associated with far fewer greenhouse gas emissions over their lifetime than traditional building materials such as concrete and steel [49–52]. While concrete production accounts for around 8% of world CO_2 emissions [53], wood construction represents a lower concrete energy consumption compared to steel and concrete production [29]. Buildings using steel and concrete contain and consume 12- and 20% more energy, respectively than wooden buildings [27]. Moreover, products made from sustainably sourced wood replace other fossil-intensive substitutes, like concrete and steel [54–59].

Prefabricated timber frame offers lightweight and customizable solutions with multiple thermal insulation options to meet specific design needs [35, 60–62]. Prefabrication is highly efficient [63], high quality [64], and low cost [65], contributing to more than 50% minimization of construction waste and 70% wood formwork savings [66–70], compared to traditional construction methods. While prefabrication offers environmental friendly solutions with low carbon-emission and high utilization technology, it also reduces carbon emissions during transportation and ultimately contributes to an ecologically sound engineering approach [71, 72].

3. Research methods

This chapter was conducted in the form of a literature review including international peer-reviewed journals and similar research projects, and interviews professionals involved in the construction of extra stories during the PKRKP project (construction of wooden apartment buildings for growth in Pirkanmaa between 2019 and 2021). This project includes the city of Metsäkeskus and Tampere, as well as 14 municipalities and 15 companies in the Pirkanmaa region.

It is worth mentioning here that this chapter focused on housing and real estate companies. As responsible parties, they play a critical role in renovating and maintaining old apartments in Finland [16], where around half of the Finnish population lives [73]. In this study, semi-structured interviews were moderated as the process allowed for interviewer and interviewee interactions and various views encouraged the generations of new ideas beyond those originally explored [74].

Interviews were conducted with seven construction professionals who are part of a wooden extra story construction project and a housing company. The participants were—1. property development manager (from contractor side); 2. extra story construction consultant (from developer side) 3. city planner (from municipality); 4. project director/city planning (from municipality); 5. project director/city planning (from municipality); 6. CEO, associate, architect (from architectural design office); 7. CEO, associate, housing manager (from housing company side); and 8. member of the board of directors of a housing company (from housing company).

During interviews, the board of directors/representatives of the housing company were asked about mapping the progress of the project and the current situation, project burdens, the outcome of the project. The planning authority (city planner) was asked about city strategy and city plan change. The architect/chief designer was asked about project progress—contacting the housing company and combining extra story construction and building renovation. The housing manager was asked about project progress, and combining extra story construction, and building renovation. Extra story construction consultant was asked about project progress—contacting the housing company. Builders/contractors were asked about their organizational background. All participants were asked to report whether they had any other thoughts other than the specified themes in the other remarks section.

Interviews underlined the main points in the four stages of extra story construction—(1) feasibility study; (2) project planning; (3) implementation planning; and (4) construction, as summarized below.

4. Interviews on wooden extra story construction

The interviews highlighted the following key findings regarding four main phases of extra floor construction.

4.1 Feasibility study

Features for the feasibility study phase, in which the construction conditions of the extra stories are scrutinized and professionals in the construction and real estate sectors are contacted, are as follows:

City planning	It is important to determine the possibilities of permits or deviations from the city plan. These issues include how the extra floors relate to the surrounding buildings and the shading effect.
Parking space	The amount of parking required for the area is determined on a case-by-case basis by city authorities.
Information flow	Information provided in the drawings may vary from site to site. Completion of building drawings can be costly if the information is sought from the city's building inspectorate.
Load-bearing capacity	The housing or real estate company must compile existing drawings of the building to inspect the structure. Load-bearing capacity can be calculated directly from the drawings but also may require structural analysis.
Existing regulations	New regulations may affect operations; for example, if extra stories are added to an apartment without an elevator, retrofit elevators are needed.

4.2 Project planning

Themes for the project planning phase, in which the conditions of the project are determined, considerations are as follows:

Sale of building right	When an additional extension building right is sold to a third party, a recourse fee is allocated to the shares; also, a separate compensation may be determined which may include the costs and extra stories used in the project.
Building codes	They affect the implementation of the project, regardless of the building material from which the extra stories are constructed. For example, Finnish fire codes must be considered at an early stage, especially when designing a wooden extension where the codes allow the construction of two wooden extra stories.

4.3 Implementation planning

In the implementation planning phase, in which measures are taken to increase the building right, considerations are as follows:

City plan change	The permission of the landowner and material showing the effect of the extra story on the immediate surroundings of the property is required. Such studies may include elevation plans and drawings of their suitability in the immediate environment, a site drawing, and a building stock inventory.
Building right	In case the building right of the extra stories is sold to an external developer, a tender can be made after the building right has been added to the land.
Terms and conditions	The company managing the property to be extended vertically may set conditions for the sale of the building right. The terms and conditions can protect the interests of the company.

4.4 Construction

In the construction phase, issues are as follows:

Effective information flow	Residents and stakeholders should be kept informed of construction site progress, schedules, and potential times when construction significantly impairs residents' comfort of life.
Appointing a representative	In planning critical milestones, such as demolition work, it is an effective method for a housing or real estate company representative to attend site meetings and negotiate available times for work to minimize inconvenience from construction to residents.

5. Conclusion

Due to the lack of research on extra floor construction, it was not possible to provide a discussion of the similarities and dissimilarities of the Finnish practice with the applications in other regions. This chapter analyzed the different stages and advantages of wooden extra story construction from the standpoints of Finnish housing and real estate companies through interviews with professionals who have worked in these projects.

The key points from this chapter on the four phases of the wood extra story can be summarized as follows—(a) in the feasibility study, project planning primarily focuses on property condition and potential improvement targets, as well as other considerations, for example compliance with current regulations and parking arrangements; (b) in project planning, application of extra stories, is thoroughly examined, construction costs, profits and the sale of building rights are discussed; (c) in implementation planning, issues related to building rights, city plan change, and conditions of the company that manages the property play an important role; and (d) during construction, frequent information updates are made to residents regarding the site arrangements and the construction program.

Wooden extra story construction, which necessitates commitment, investment, and cooperation between interested parties, has great potential in construction technology, commissioning mechanisms, and ecological engineering solutions. Additionally, this sustainable approach with prefabricated timber solutions has many benefits in terms of economic, energy efficiency, esthetics, and environmental. In this sense, it is thought that this study will increase the popularity and prevalence of wooden extra stories, as in the case of Finland, thus contributing to the greater use of more sustainable materials in renovation projects and contributing to the ecologically sensitive engineering approaches to meet the challenges arising from climate change.

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