Wooden Additional Floor in Finland

Subjects: Plant Sciences
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One of the most effective ways to cover real estate development and renovation processes by improving functionality and energy efficiency is wooden additional floor construction. The scattered information is mapped out, organized, and collated on the current state of the art and the benefits of this practice including its different stages, focusing on the case of Finland. The topic is presented in an accessible and understandable discourse for non-technical readers. By highlighting the benefits and opportunities of this sustainable application, it will contribute to increasing the awareness of wooden additional floor construction, which has many advantages, and therefore to gain more widespread use in Finland and other countries.

Keywords: wood ; additional floor construction ; sustainability ; Finland

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Among the targets of the European Union's 2050 Energy Roadmap are the decarbonization of increasing energy resources, making more use of renewable energy, and improving energy efficiency [1][2]. In line with these sustainable goals, Finnish building regulations were revised and developed, allowing new construction methods to be more energy-efficient [3][4][5]. Most of Finland's building stock consists of buildings that were erected before the 1990s, have very low energy efficiency, and are mostly in the renovation era [6][7]. More than 30% of residences, which constitutes a substantial part of the building inventory in Finland, are apartment buildings constructed in the Finnish suburbs in the 1960s and 1970s and need refurbishment [8][9][10].

The thermal insulation of these Finnish suburban apartments was poor, and at that time, no regulations or targets were set for this in Finland, and as a result, these buildings needed a serious energy upgrade [11]. Energy upgrade strategies, especially for the old housing inventory, should be adopted as an important approach to increase energy efficiency because, with the erection of new buildings, the rate of renewal of the building stock has not even reached two percent per year [12]. Overall, besides the lack of equipment and poor technical conditions, among the most important problems of Finnish suburban apartments is poor energy efficiency [13][14].

As in many other countries, it takes a lot of investment and government subsidies to renovate a building by increasing its energy efficiency in Finland [15][16][17][18]. Additionally, it is difficult to find a contractor who can undertake or is willing to undertake suburban apartment renovations, and it is often necessary to seek and hire more than one contractor for a project in Finland [19]. Real estate and housing companies play a key role in renovating old apartments in Finland [20]. There are more than 60,000 flats where almost half of Finland's population resides [6]. Real estate and housing companies that require financing instruments to refurbish and improve their properties often play an important role in the maintenance and modernization of apartments [21]. In addition, renovation projects involve excessive work and strong coordination of residents as well as building managers and housing companies [22]. In practice, building renovations are a slow, expensive, dirty, and destructive process [23]. This is mainly because refurbishment projects in Finland often use operational models created for new construction [24].

It is worth mentioning here a local Finnish challenge stems from the ownership of buildings [25]. Single people have their flats and a piece of land below. They co-manage housing companies that must make a joint decision to fund their new investments, where redevelopments are often financed by a bank loan. This amount is then directly attributed to the occupant's share of the total renovation costs. Parking space is another challenging issue if parking lots need to be constructed to replace old parking lots and offer additional parking spaces.

In Finland, one of the most effective ways to cover real estate development and renovation processes by improving functionality and energy efficiency is the construction of an additional floor [24] (**Figure 1**). When the building height and the number of building stories increase or the roof form changes, the terms additional floor, roof, or elevation construction are used [26]. Furthermore, additional floor construction provides numerous opportunities and benefits such as increased owner income, short-term income to housing companies by selling the building rights or areas of additional floors, as well as a relatively lower carbon footprint, increased gross floor area, and improved building appearance [26][27][28].

(a) (b)

Figure 1. Wooden additional floor project examples: (**a**) (Image courtesy of Aino Hirvilammi, Eetu Salminen, and Joel Lehtola); (**b**) (Image courtesy of Risto Piirainen and Silja Suitiala).

Important issues requiring special attention in additional floor projects in the Finnish context are as follows [29]: (i) Economic feasibility: This consideration, which has become more important with the sale of building rights to the outside party that built the additional floor, poses a significant problem if the commercial return of the additional floors is not properly estimated, which means the targeted profit for the project will not be achieved; (ii) change in the city plan or deviation from the city plan: This issue, which directly affects the right to build on the land, also has an impact on the amount of property tax; (iii) finding a suitable contractor: As the cost of maintaining the property increases over time, it is very important to find a contractor who will build the additional floors as soon as possible; (iv) obtaining expert opinion: The presence of an expert is especially important for identifying and then minimizing risks. In some municipalities in Finland, the procedure for making changes to the city plan is suspended unless the relevant expert is included in the project.

The intensification of Finnish urban environments is an adopted Eurocentric goal in tackling climate change, driven by the needs of continued urbanization and the environmental impact of low-density urban structures. In this sense, European building retrofit and urban renewal applications have shown that the expansion of building volumes, such as the construction of additional floors, has significant potential [25].

Technical features (e.g., structural and architectural issues) of reinforced concrete apartment blocks built between the 1960s and 1980s in Finland generally allow the construction of additional floors, often designed as lightweight structures [29]. They are suitable for these implementations with both their structural capacity and flat roof. The current Finnish fire code also gives the green light to the construction of additional floors [30]. The Finnish fire regulations make it possible to construct the top floor of a class P1 building with a timber-framed additional floor without automatic extinguishing equipment if the building has no more than seven stories. Two additional stories require a sprinkler system on the topmost old floor and additional floors (**Figure 2**). There are three main fire classes, P0, P1, and P2, used for apartments in Finland [30]. While the P1 fire class represents the structural frame in which non-combustible materials such as concrete are used, wooden load-bearing systems are classified in the P2 category. On the other hand, the P0 category is based on the calculation method and is used when deviating from standard table values.

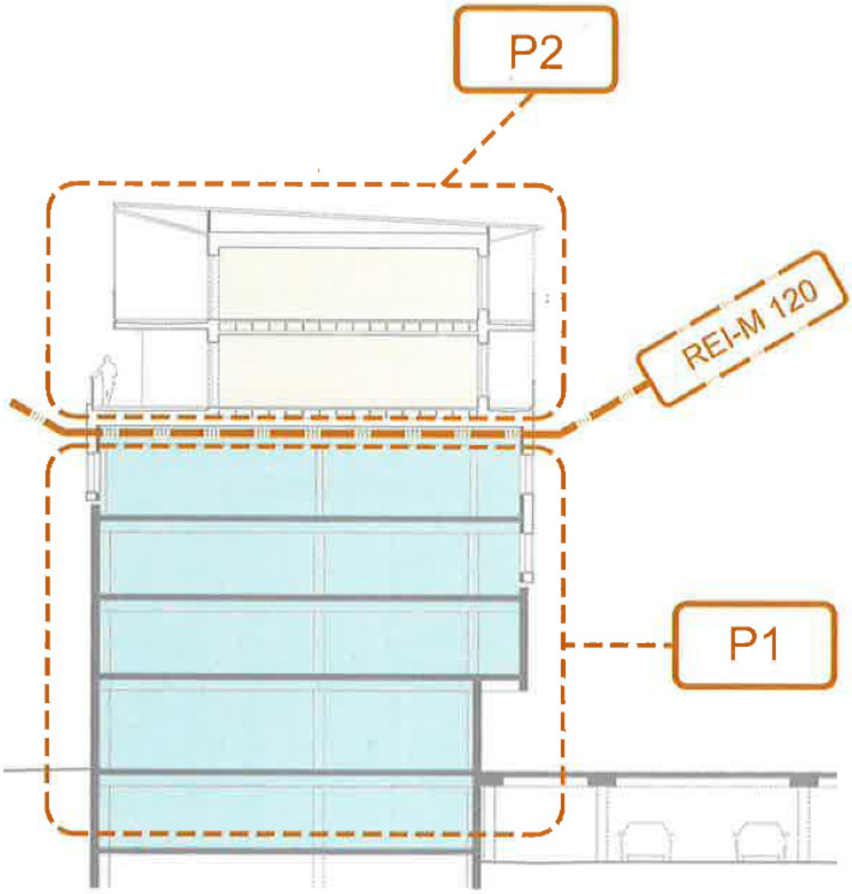

Figure 2. Two-story-high wooden additional floor (Image courtesy of Petri Pettersson).

Material selection is important for refurbishment in terms of sustainability. Considering sustainable construction concerns, the renovation materials must be environmentally friendly, long-lasting, renewable, reusable, and their production must require the least amount of energy and produce a minimum amount of greenhouse gas emissions [31][32][33][34]. Studies in the literature have indicated that timber has numerous benefits over traditional building materials such as brick, concrete, and steel, and with its environmentally friendly properties in particular, timber is a suitable material for renovation [35][36][37][38][39][40][41].

In this context, wooden structures are considered lower carbon structures and represent lower embodied energy consumption compared to non-wood structures [42][43][44][45][46][47]. In addition, buildings using concrete and steel structural systems embody and consume 20% and 12% more energy, respectively, compared to buildings with wooden structures, so structural material selection plays an essential role in the amount of embodied carbon [48]. Furthermore, both in production and on-site construction, concrete and steel structures utilize 50% and 7% more resources compared to wooden structures, generating 16% and 6% more solid waste, respectively [49]. Overall, the construction of wooden buildings is in line with the sustainability goals of the European Union [50], where timber as a building material is considered to lower carbon emissions in the building construction sector and is a method of transitioning to a sustainable bio-economy.

The construction phase of timber buildings can deliver considerable savings with over 50% faster assembly times compared to traditional construction materials [51]. Timber construction offers light and prefabricated alternatives with various size and thermal insulation options to respond to special demands [52][53][54]. The prefabrication process ensures that facade elements such as doors and windows are integrated into the prefabricated units (**Figure 3**) [55]. In addition to being used as a construction material, after completing its service life, timber can be reused as a raw material for other buildings, or it can be burned instead of fossil fuels as a last resort [56][57][58].

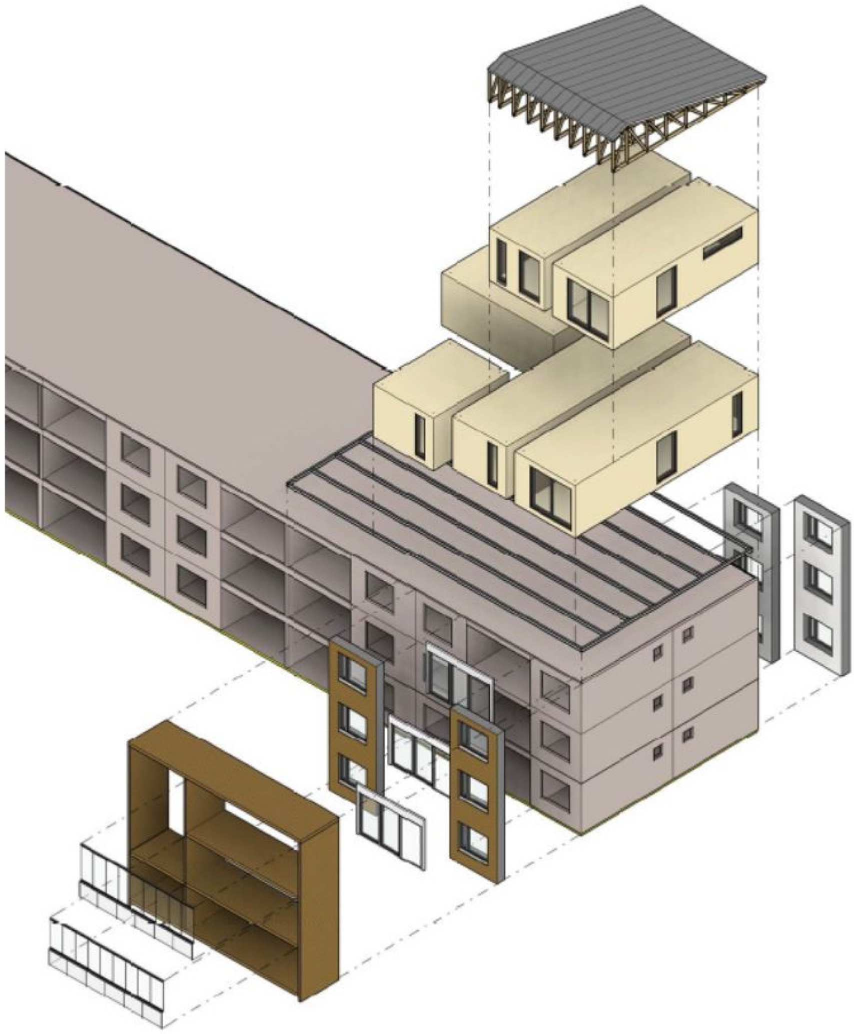

Figure 3. Additional floor project with wooden prefabricated units (Image courtesy of Simo Rasmussen).

The attitudes of residents towards new construction methods (e.g., a wooden additional floor) have an important role in the spread of these practices [59]. Moreover, the positive attitude of residents is a critical aspect in the effective execution of extensive refurbishment [60]. In this sense, the survey by Karjalainen et al. [25] showed that participants generally assessed the construction of wooden additional floors positively and thought that it would contribute to the attractiveness of the residential area.

The combustibility of timber may limit its use as a construction material in Finland, as in many countries, due to constraints on building regulations [61][62][63]. Various studies have been carried out recently on the fire behavior of wooden buildings around the world, aiming to provide fundamental data on the safe use of wood (e.g., [64]). As a result of extensive testing, new fire design concepts and models were developed, and existing advanced knowledge in the fire design area of wooden structures together with technical precautions, especially well-equipped fire services and sprinkler systems, ensure the safe use of wood in a wide range of applications as seen in the building code relaxations introduced in recent years [65]. In this sense, fire safety engineering and performance-based design offer benefits and challenges for the use of timber in buildings, where the performance-based approach is primarily based on the use of fire engineering principles, calculations, and modeling instruments (e.g., structural models, thermal models) to meet building regulations, considering fire modeling, full-scale structural fire experiments, and experience from fire accidents in timber structures [66][67][68][69]. Additionally, the following considerations stand out in terms of the implementation of fire safety design in wooden structures [70][71][72][73]: Manual firefighting, sprinklers, encapsulation, fire retardants, fire performance and fall-off times of protective systems, the fire performance of connections between structural timber elements, details to prevent the internal spread of fire, external fire spread in the same building, and quality assurance. Furthermore, timber and steel structures have some similarities and differences in terms of fire safety measures [65][74]. Some fire regulations, such as those in Canada, encourage full encapsulation of timber frames to ensure equivalent fire safety to the non-combustible steel frame structure. In terms of performance-based design, performance-based formulations of requirements for timber structures can be considered to provide a fire-safety equivalent to regulatory steel structures. Regarding structural modeling, wooden structures are usually easier to model than steel structures because the wood has poor thermal conductivity and does not undergo considerable thermal expansion. In the manual fire extinguishing strategy, the fire risk will be greatly reduced if immediate action is taken to contain the fire, and this reduction in fire load is adjusted for steel frames. This method is also permissible for timber structures. Moreover, in terms of external fire spread in the same building, timber facades can also be used as fire-resistant facade cladding in steel structures.

Issues with wooden structures, especially sound insulation and moisture, require special insulation and protection techniques. To obtain good air-borne sound insulation, the partitioning wall and intermediate floor structures should be built in layers and the layers should be separated from each other so that the sound does not pass through the structure [75][76]. On the other hand, humidity issues lead to both reduced durability and mold growth, which can affect indoor air quality and have adverse health consequences [77]. The best strategy for providing a moisture-resistant structure is to ensure that the wood is not exposed to water or high relative humidity for extended periods. Neglecting moisture safety can mean a high risk of damage, with extensive costs and consequent time delays for research, decontamination, or material replacement [78].

Wood-based composite materials and wood frame-based hybrid structures are among the important topics in today's wood construction literature. In general, owing to the destruction of forest resources and recently developed technologies for wood-based composite materials in particular, engineered wood products have gradually replaced traditional materials for residential construction [79]. These materials are produced from similar materials based on wood products, e.g., timber or lumber processed into boards, or wood chips [80], and the residential and commercial building construction industry is among the areas where wood-based composites are most in-demand [81][82]. On the other hand, the idea of hybrid structures that combine multiple materials, such as timber, along with steel and/or concrete, is gaining increasing acceptance in the engineering community [83]. Moreover, hybridizing timber with other structural materials is one of the most popular approaches for designing high-rise timber buildings [84][85][86][87] as in the case of Brock Commons Tallwood House (Vancouver, BC, Canada, 2017) [88].

The three critical components of timber frame construction are the floor, the roof, and the load-bearing wall, which have significant effects on occupants' comfort. The wood floor, the most common system component, is in frequent physical contact with building inhabitants [89]. The dynamic movement of people or objects caused by defects or deficiencies in the structural performance of the floor can cause occupant discomfort. Movements, e.g., walking, running, jumping, can create structural vibrations on the wooden floor, which adversely affect the efficiency of work and quality of life [90]. However, environmental excitation and impact excitation vibration tests as well as comfort analyses of timber floors offer solutions to these undesirable situations [91]. In addition, particularly nowadays, when standard structures are supported by contemporary technologies such as wooden floors combined with underfloor heating, it is necessary to meet technical guidelines and specifications during the operation of the floor as a whole [92]. Moreover, in line with the 'smart building' concept, wood, namely wood flooring, is used as an ideal material to be applied in triboelectric nanogenerators for large-scale applications in smart houses [93]. This ensures that mechanical energy (for example, the movements of residents) is directly converted into useful electricity [94][95][96][97].

Although there are numerous research studies on different construction solutions with the use of engineered timber products with related technical features (e.g., [98][99][100][101][102][103][104][105][106][107][108][109]), several studies have focused on the use of wood as a building material from the viewpoint of construction professionals (e.g., [110][111][112][113][114][115][116][117][118][119]) and consumers or users (e.g., [120][121][122]). On the other hand, to date, there has been a limited number of studies on wooden additional floor applications, especially in the housing construction industry.

This entry maps out, organizes, and collates scattered information on the current state of the art, as well as benefits and challenges of wooden additional floor projects with their different stages, focusing on the case of Finland, and presents it in an accessible and understandable discourse for non-technical readers. This entry also provides a methodical literature analysis on international peer-reviewed studies and research projects. By highlighting the advantages and opportunities of these sustainable practices, the entry will contribute to an increase in the awareness of wooden additional floor construction, which has many advantages and therefore help to gain more widespread use in Finland and other countries.

In this entry, timber or wood refers to engineered timber products [123][124], e.g., cross-laminated timber ((CLT) is a wood panel product made from gluing together layers of solid-sawn lumber), laminated veneer lumber ((LVL) is produced from veneer and is designed for structural framing where high strength and rigidity are required), and glue-laminated timber (glulam) ((GL) consists of layers of dimensional lumber glued together with durable, moisture-resistant structural adhesives).

The remainder of this entry is composed as follows: First, a literature survey is provided. This was followed by a section on the benefits, challenges, and drawbacks of wooden additional floor construction. Finally, the conclusions and prospects of the research are presented.

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