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The Role of CLT in Residential Sustainability

Redefining Housing Adaptability in Athens



CLT sustainability

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Student background

My academic engagement with the construction field began during my undergraduate studies in Civil Engineering, where I developed a foundation in project management and conducted thesis research on various construction materials.

This initial connection expanded with my pursuit of a second bachelor's degree, focusing on architecture. At the University of Innsbruck (LFU) in Austria and the Technical University of Munich (TUM) in Germany, my studies emphasized parametric design methodologies and spatial investigations.

To complement this architectural foundation, I pursued a master's degree in Investment and Finance at Oxford Brookes University, which provided a comprehensive understanding of financial and investment strategies relevant to the built environment. These academic milestones ultimately led to my current master's program in Architecture and Urban Design at Chalmers University in Sweden, where my focus is on housing and urban design.

This extensive academic background has been further enriched by several years of professional experience in the construction and real estate sectors, allowing me to bridge theoretical knowledge with practical application.

The aforementioned background provides a comprehensive foundation for exploring the implementation of Cross-Laminated Timber (CLT) within an urban context where prior experience with this material is limited. By integrating sustainable construction methodologies, such as prefabrication and modularity, this study aims to develop flexible and cost-effective housing solutions that address critical environmental, social, and economic challenges in the built environment



Acknowledgement

I would like to express my sincere gratitude to my thesis supervisor for his invaluable guidance and support throughout this journey. I am also deeply thankful to the professors of the Department of Healthcare & Housing architecture for the knowledge they shared with me, as well as to the experts who generously offered their insights during interviews and discussions, especially Adam. Last but not least, a heartfelt thank you goes to my colleagues and friends for their encouragement, and to my family for their unwavering patience, love, and belief in me.

Abstract

Many cities face various problems due to financial and environmental crises. Athens is not an exception to this rule. Intensive heatwaves, floods, social inequality, lack of green spaces and affordable housing as well as unsustainable building materials, diminishing living conditions and aesthetics are some of those problems. To tackle some of these problems as efficiently as possible, this thesis explores the idea of flexible housing design in Athens with CLT and the implementation of prefabrication and modularity as part of an existing framework.

The use of Cross-Laminated Timber (CLT) is not new in Europe with several examples in the most renowned cities. CLT is a sustainable solution known for its lightweight yet strong structural properties. It offers a modern alternative to conventional construction methods and is well-suited for multi-story residential projects.

The current thesis will examine the advantages of using this construction method in a southeast Mediterranean context in comparison to traditional concrete-based ones. The main aim is to develop a proposal that offers a sustainable design solution for implementing CLT elements on an existing concrete framework. This could be achieved mainly through spatial innovations as much as a sustainable construction strategy that could be a test example for further use of CLT in similar urban contexts.

The design proposal will examine the properties of CLT, its use in prefabrication for faster, cost-effective building, as well as design techniques to achieve sustainability and adaptability. The design proposal envisions the transformation of an existing abandoned building in Athens, to a modern residential prototype constructed of CLT. The research methodology will use quantitative, qualitative, mixed and comparative methods and will have the following sequence.

The first theoretical part includes the argumentation of the CLT advantages as a possible solution in Athens' urban environment. The following part refers to the proposed case study, and the re-evaluation of the achieved result, adding to that, following the assumptions and future references. Lastly, the whole project will be finalized, exhibited, and reported.

Keywords: residential design, sustainability, modular prefabrication, CLT

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Introduction

Purpose - Expected Results

The expected results of this thesis encompass both academic and practical development. The research evaluates the overall environmental and construction benefits of CLT compared to conventional methods, advocating CLT as a sustainable alternative in the Mediterranean context.

A theoretical framework will be developed, integrating sustainable design principles and adaptable housing design techniques. This framework will guide the design proposal and serve as a guideline for future attempts to integrate CLT into sustainable housing projects in Athens.

The design deliverables will include a fully functional academic test project, suggesting design techniques of implementation of CLT on existing concrete framework within a site plan, located in Athens. The project will feature detailed architectural drawings, 3D models, renderings, technical specifications, construction methods, and installation processes for the CLT modules.

Additionally, the thesis aims to promote awareness and acceptance of CLT by showcasing its benefits in a local context, influencing architects, builders, and policymakers to explore its construction potential. Ultimately, the findings will lay the groundwork for applying CLT and other sustainable materials in urban settings within southern climates.

Research questions

A. What are the environmental and structural advantages of using CLT in comparison to traditional construction methods for the housing sector in Athens, Greece?

This question focuses on the environmental impact, structural benefits, and preferences of CLT compared to conventional construction practices (reinforced concrete) in the context of Athens' urban environment and climate.

B. How and what Cross-Laminated Timber (CLT) construction techniques could be implemented to make the housing sector in Athens more adaptable and sustainable?

This question will investigate the feasibility aspects of CLT, exploring prefabrication, modularity, and CLT construction processes that could result in more cost-efficient residential projects without compromising on quality and aesthetics.

This question also explores the social and architectural dimensions, addressing how the (CLT) housing project can be designed to accommodate lifestyle and aesthetic preferences, while being energy-sustainable and adaptable to the urban scene of Athens.

Motivation – Existing situation

Cities, particularly in Europe, are at the forefront of energy demand pressures and climate change, with urban areas accounting for 80% of energy consumption. Urbanization is rapidly increasing, with 83% of Europeans expected to live in cities by 2050 (European Union, n.d.; United Nations, 2017).

Athens especially has undergone significant population growth and urban expansion over the past 170 years, increasing from 9,000 inhabitants in 1824 to 3.75 million in 2014, encompassing 58 municipalities within its metropolitan area. Since 1951, suburban areas have experienced a 95% increase in population, reaching 2.30 million by the early 2000s. While contemporary growth has slowed, Athens remains one of the densest cities globally and by default, there is an increasing demand for sustainable housing solutions. (Ferrante et al., 2020).

The city's expansion, largely unregulated and driven by amendments to the General Building Code of 1929, has led to highly dense urban blocks, a lack of green spaces, increased traffic congestion, inadequate public services, and severe air and noise pollution. The “continuous building system,” introduced in the 1950s and prevalent until the 1990s, created uniform street façades with closely attached buildings. This design also produced “urban voids”—unutilized inner-block courtyards that serve only to provide daylight access to rear façades. In addition, the widespread presence of flat roofs, primarily used for maintenance purposes. These underutilized spaces, aside from their negative impact, hold significant potential for urban redevelopment interventions (Ferrante et al., 2020).

The city in general faces the extensive use of concrete, which contributes significantly to the urban heat island effect, where urban areas experience higher temperatures than their rural surroundings. All this old building stock of the city lacks of modern energy-efficient design. The majority of buildings often have inadequate insulation, outdated heating and cooling systems, and inefficient lighting (Mavrakou et al., 2018).

The New Building Law No. 4067 establishes a framework for enhancing energy efficiency at both architectural and urban scales, positioning Athens as a relevant case study for energy performance and environmental sustainability. Addressing many of the aforementioned issues requires a mix of natural and passive design strategies, innovative technologies, and sustainable urban planning (Busby & Dean, 2023).

By integrating nature-based solutions and energy-efficient designs, Athens can mitigate climate change impacts while enhancing urban livability and resilience (Ferrante et al., 2020). In this context, CLT emerges as a sustainable construction method, offering a notable reduction in carbon emissions compared to concrete and steel (Liu et al., 2016).

In addition, CLT provides structural stability, thermal and sound insulation, and fire resistance while promoting environmentally responsible building practices, with prefabrication and modularity. Based on that, it could be an asset of sustainability, offering a great alternative to traditional construction methods (Guo et al., 2020).

Method & Process

Research methods in academic writing refer to the systematic approaches used to collect, analyze, and interpret information to develop a well-supported argument or analysis. The choice of research method depends on the discipline, research objectives, and type of data required (Àkànle, 2022). For the specific thesis, the research methods that were processed according to the academic research principles are the following:

Quantitative:

- Extract numerical data from already built projects concerning the efficiency of CLT (Carbon emissions, durability, fire resistance, noise insulation, etc).
- Interview (How professionals deal with similar projects, considerations & thoughts)
- Growth financial approach of the industry.

Qualitative:

- Literature review (adaptable housing theory, sustainability of CLT structure, existing situation, regulations)
- Context analysis
- Sketching
- Drawing
- Case studies/ Reference projects
- Site analysis

Comparative analysis:

- Comparison between the most relevant selected reference projects
- Different locations (climate, urban projects, market overview)
- Project extent (smaller – bigger scale)

Design Research:

- Speculative design: visualization of hypothetical design solution to address the existing situation (design proposal – explanation of how it deals with the referred problems of the local concept).

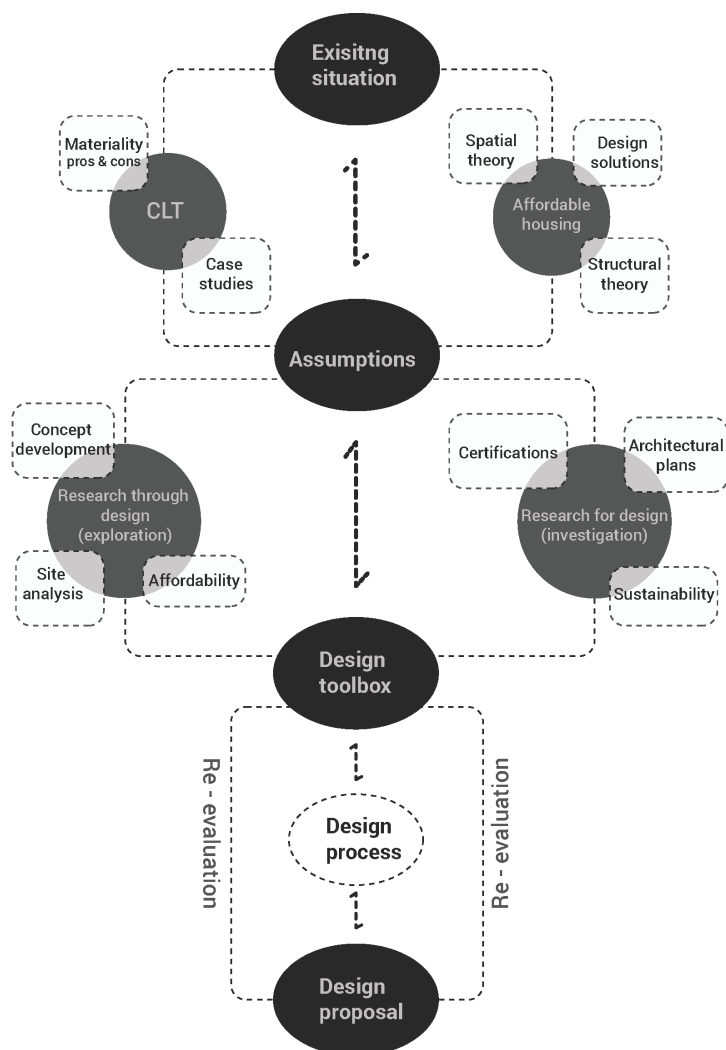


Figure 01: This diagram presents the process of the thesis.

Note: Created by the author.

- Design experiment: work with different floor plan ideas to investigate the proposal efficiency through design.

The process of a thesis is structured with an introduction that explains the research challenge, objectives, and framework. A well-supported academic argument is ensured by the conclusion, which summarizes findings, highlights contributions, and makes recommendations for additional research.

The introduction will state the problem, briefly describe the proposed design solution and the relevant theoretical framework for the thesis.

The investigation phase will explore the advantages of the proposed solution. More specifically, this will involve analyzing the structural and the spacial systematics of timber projects, focusing on modularity and prefabrication at a conceptual level. This research will examine existing housing projects made with Cross-Laminated Timber (CLT) to leverage its inherent benefits. Additionally, traditional and vernacular building techniques will be studied for inspiration in adapting these principles to contemporary design and existing build situations.

The exploration phase will utilize research through design. In this stage, design guidelines will be developed, leading to the creation of a design proposal based on earlier findings. By bridging theory and practice, this phase will involve testing conceptual designs within the existing structural context, aiming for optimal outcomes. The exploration will primarily consist of creating digital and physical models, simulations, and diagrams to gain empirical insights and move closer to practical design applications.

The final design proposal will emerge from this iterative process, informed by the design toolbox and the guidelines developed from the research findings.

Theoretical basis

The design phase that follows will parallel the theoretical norms of different design aspects and it will try to simulate a well function design outcome with implementation capabilities.

Sustainable Design Theory / Energy-Efficient Buildings and Passive Design

Ecological architecture emphasizes integrating natural materials and sustainable practices in construction. Using CLT aligns with biophilic design principles and sustainability goals, promoting lower carbon footprints and eco-friendly materials (Singh, 2025). This concept also connects to the broader circular economy in architecture, which stresses resource efficiency and environmental responsibility. (Kurnitski, Kalamees, & Wahlstrøm, 2020).

Urban Regeneration and Adaptive Reuse Theories

Retrofitting existing concrete structures with CLT extensions draws upon adaptive reuse theories, advocating for sustainable urban renewal.

Rather than demolishing buildings, this approach aligns with concepts aimed at extending building life cycles through innovative materials like CLT, which has gained popularity in modular construction and vertical extensions. (Smith, Griffin, Rice, & Hagehofer- Daniell, 2017)

Prefabrication and Modular Design Theory

Prefabricated CLT modules and CLT elements align with theories of industrialized building systems. These theories promote reducing construction time, waste, and costs by utilizing factory-built components (Pilathottathil & Rauf, 2024).

Delimitations

This project faces several delimitations. First, CLT is not widely used in Greece, so the analysis relies on data from other regions, which may not fully reflect Greece's environmental and regulatory conditions. Greece's lack of a domestic timber industry further complicates the research, as importing CLT increases transportation costs, making it less economically viable than in the countries with local timber production.

Additionally, incomplete site data and building drawings led to assumptions in the analysis, potentially affecting its accuracy. The absence of a regulatory framework for CLT in Greece further limits the applicability of these findings in terms of building codes and standards.

According to these limitations, this thesis will have a superficial approach to some construction parts, for example the plans refer exclusively to the residential parts of the building and do not include the commercial areas or shared/common spaces.

The construction details provided will focus on the merging of the concrete framework with the prefabricated modules and will be presented only fragmenal parts. In addition, a detailed cost analysis and project management of the construction is not going to be displayed. The main focus is the result to provide an idea " a guideline " of a sustainable and adaptable concept and not a fully accomplished project.

Project context

The site is situated in a prominent location, facing one of the most central squares in Athens, making it highly visible and significant in the urban context. Secondly, despite its centrality, the area is characterized by low social standards and economic depreciation, which underscores its need for social upgrade. Finally, the existing building on the plot, which has remained abandoned for over a decade, is at the stage of a completed concrete structural framework. This condition presents a unique opportunity for transformation, offering considerable potential for adaptive reuse and redevelopment.

<i>Location of the project:</i>	Athens, Greece
<i>Issues to tackle:</i>	Lack of affordable housing, non environmentally friendly constructions, extreme climate conditions , aesthetics, green strategies, and optimization of living conditions.
<i>Materiality & Typology:</i>	CLT prefabricated modules/ CLT add-on existing concrete framework/ typology of Mid-rise Building.
<i>Research:</i>	Researching the structural properties of CLT, how the material could be used in the building process (prefabricated – part of the existing), urban planning regime in Athens, and green certification.
<i>Design proposal:</i>	Designing of a multi-family housing project in an existing site in Athens, with prefabricated CLT modules as an add-on to the existing concrete framework.
<i>Connection with the profile:</i>	The fact that the project will be a residential prototype makes it very compatible with the profile. In addition, the proposal deals with an existing problem and tries to bring something new to the urban environment of Athens. The proposal has the potential to be very sustainable and efficient solution on the current weather and urban conditions.

Table 01: Details of the case study.

Note: Created by the author.

AI disclaimer

I assume full responsibility for my work and I am capable of justifying the choices I made regarding its content. This includes engaging in discussions about and defending the role AI played in shaping my thesis and demonstrating a clear understanding of how it contributed.

I state that AI was employed restrictively in this context, primarily focusing on rectifying vocabulary, syntax, and grammar within the text. Additionally, AI was utilized to assist the author in identifying and locating relevant sources related to the subject matter.

Theoretical framework

Overview of Cross Laminated Timber (CLT)

An uneven number of layers of planed wood are used to create cross-laminated timber, (CLT), a timber-based building material that is manufactured as panels. Typically, three, five, seven, or nine layers are utilized. Finger-jointed planks, or “boards,” are arranged side by side to form each layer. (Saint-Gobain, 2020).

Every board layer is positioned perpendicular to its neighboring layers. After that, the layers are crushed and adhered to one another. The boards in each layer are also bonded together side to side along the edges when certain manufacturers employ edge-glued boards. (Saint-Gobain, 2020).

CLT panel elements can be either two-dimensional (2D), or three-dimensional (3D), which are often pre-finished and assembled at the job site for later external finishing and placement. (Saint-Gobain, 2020).

How is CLT made

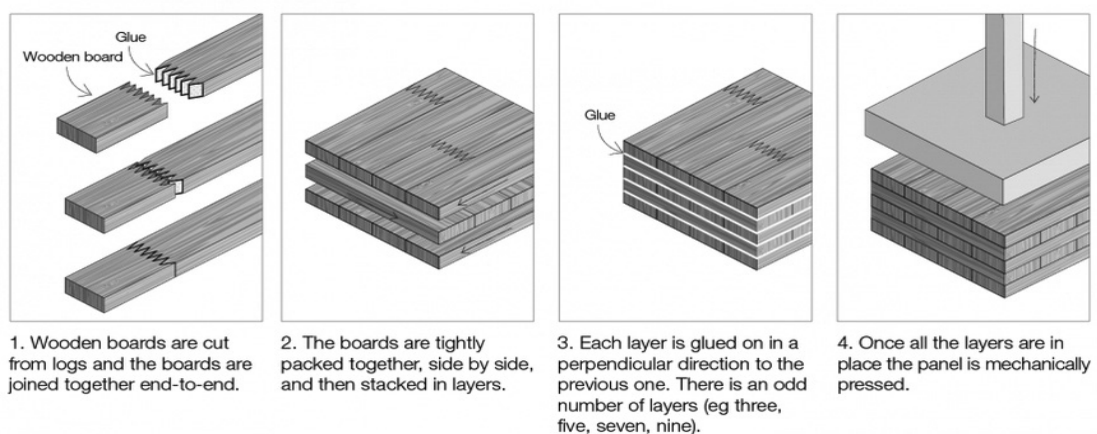


Figure 02: CLT - The ultimate guide to CLT & how to protect it. / Note: Reprinted from SIGA (2025).

Market overview

The European Cross-Laminated Timber (CLT) market is undergoing rapid growth, particularly in Western Europe (IMARC Group, 2025). The DACH region (Germany, Austria, and Switzerland), leads production, with Austria alone hosting multiple manufacturing plants. Even though, CLT, in certain cases, could be slightly more expensive than conventional materials, sustainability and construction efficiency continue to drive demand (CBI, 2017). The market is projected to grow at a compound annual growth rate CAGR of 8.95%, with volume rising from 1.9 to 4.2 million cubic meters from 2025 to 2033 (IMARC Group, 2025).

The key market drivers for CLT can be categorized into three main domains: environmental policies, technological advancements, and efficiency.

Policies promoting green building practices have positioned CLT as a viable and eco-friendly alternative to traditional materials. Technological advancements in precision engineering, digital modeling and prefabrication techniques have enhanced the quality, scalability, and efficiency of CLT production and application and lastly, CLT's efficiency rises by shorter construction times, lower labor costs, and reduced transportation expenses (Busby & Dean, 2023).

The market segmentation relevant to this analysis focuses on CLT applications, particularly in residential construction, which represents the largest segment followed by commercial uses. Key industry stakeholders identified by the IMARC Group include Stora Enso Oyj, KLH Massivholz GmbH, Binderholz GmbH, Mayr Melnhof Karton AG, and Hasslacher Holding GmbH. These firms could serve as potential material providers for projects in Greece, offering post-sale analyst support of 10 - 12 weeks and 100% customization options. (IMARC Group, 2025)

Despite limited local forest resources, Greece has the potential to integrate CLT into its building sector to align with European sustainability goals. Leveraging its strategic location, the country could position itself as a regional hub for CLT trade market by importing certified panels or prefabricated modules from major producers like Austria and Germany. These imports could help modernize the construction industry and support the transition toward more sustainable building practices.

Advantages of CLT

One of the primary objectives of this thesis is to assess whether CLT serves as a viable alternative to conventional construction methods in southern environments.

To address any given concerns, a comprehensive review of academic papers, articles, and brochures from well-documented case studies was conducted. This research determines as followed some of the most significant advantages associated with CLT construction.

Cost effectiveness: CLT weighs approximately four times less than concrete, reducing foundation loads and shipping expenses (Gu, Liang, & Bergman, 2020).

Design flexibility: A CLT panel's thickness can be easily increased to enable larger spans with fewer internal support components. CNC machinery is used by manufacturers to precisely cut panels and apertures, frequently according to extremely strict tolerances (within millimeters). Additionally, basic tools can be used to make field adjustments when necessary. (Gu, Liang, & Bergman, 2020)

Fast installation: Panels are prefabricated and thus assembly time is considerably decreased, resulting in more efficiency, lower capital costs, and speedier occupancy. Openings for doors, windows, staircases, service channels, and ducts are among the wall, floor, and roof components that can be pre-cut. Additionally, insulation and finishes can be done before installation, which lowers the need for on-site qualified workers. (Gu, Liang, & Bergman, 2020)

Fire protection: CLT has a high fire resistance capacity due to its thick cross-section. The charring process stops further deterioration by creating a protective layer that insulates the inner layers. Furthermore, there are fewer concealed areas in CLT assemblies, which reduces the possibility of an undetected fire spreading. (Perković, Skejić, & Rajčić, 2024).

Thermal performance and energy efficiency: The U-value, or coefficient of heat transmission, of CLT is a function of panel thickness and determines its thermal performance. Panel joints fit tighter because CLT panels can be produced with precise tolerances using CNC technology, improving the structure's energy efficiency. The system has limited airflow capability due to the solid nature of the panels. Consequently, less heating or cooling energy is needed to maintain the interior temperatures of a completed CLT structure (Sirkka & Pirttinen, 2017).

Environmental advantages: In addition to its superior thermal efficiency, CLT offers a number of environmental advantages because it is made from wood from forests that are sustainably managed. According to life cycle assessment studies, wood consistently performs better than steel and concrete in terms of embodied energy, air pollution, and water pollution. Wood is the only significant building material that grows natural and is renewable. Additionally, because wood products retain carbon that has been absorbed by the trees during their growth and because the production of wood uses less energy and produces fewer greenhouse gas emissions, it has a lower carbon footprint. (Gu, Liang, & Bergman, 2020).

Less waste: CLT panels are manufactured for specific applications, which results in little to no job site waste. Plus, manufacturers can reuse fabrication scraps for stairs and other architectural elements, or as biofuel (Gu, Liang, & Bergman, 2020).

Seismic performance: The rigidity and dimensional stability of CLT panels make them an efficient lateral load-resisting solution. CLT panels have undergone thorough seismic testing by researchers, who have discovered that they perform remarkably well with little residual deformation, especially in multi-story applications. (Gu, Liang, & Bergman, 2020).

Acoustic performance: According to test results, CLT construction systems offer sufficient noise control for both impact and airborne sound transmission since the wall's mass affects acoustic performance. Because sealants and other membranes are used by builders to provide airtightness and enhance sound insulation at the interfaces between the floor and wall plates, CLT building systems have additional acoustic advantages. (Saint-Gobain Sweden AB, 2020)

Wellbeing: According to research, adding wood into the interior design promotes user well-being especially if it is complemented by green details. This type of interior prototypes increase comfort, reduces stress, and improves users everyday life psychology (Lowe, 2020).

¹ Computer Numerical Control (CNC), machining is a manufacturing process in which pre-programmed computer software dictates the movement of factory tools and machinery. The process can be used to control a range of complex machinery, from grinders and lathes to mills and CNC routers.

In general CLT could be a good choice as a construction material mainly because of all the reasons previously mentioned, such as compatibility with off-site prefabrication techniques, reduced material waste, quicker building schedules, and fewer labor and energy requirements on-site (Hanes, 2019).

Affordability

CLT has grown in popularity in the Nordic region as a sustainable alternative to typical concrete, and one crucial reason for this growth is affordability (IMARC Group, 2025).

Although CLT material costs are generally higher than those of concrete the price difference is primarily due to additional requirements such as enhanced fireproofing, extended planning periods, lack of industry standardization and construction experience (Andersen et al., 2023).

However, it has been demonstrated that expenses go down as knowledge increases. Some of the reasons are the strong supply network, reduced transportation costs, and advantageous laws. According to recent research, CLT building in Sweden can be 11.7% to 14.2% less expensive than concrete (Andersen et al., 2023).

Studies also suggest that CLT's smaller weight and reduced foundation requirements can save up to 15% on mid-rise structures (Sirkka & Pirttinen, 2017). Shorter building periods (cut by as much as two months) also lower labor costs and accelerate returns (Andersen et al., 2023).

In all this process logistics are crucial, because issues with shipping can drive up prices. To mitigate these problems, multimodal transit, local sourcing, and early-stage planning are essential (Andersen et al., 2023).

Overall, although CLT seems to be more costly at first, research indicates that with practice, like improved logistics, and legislative support, it becomes more affordable, making it more and more feasible throughout Europe and beyond.

Adaptability - Flexibility

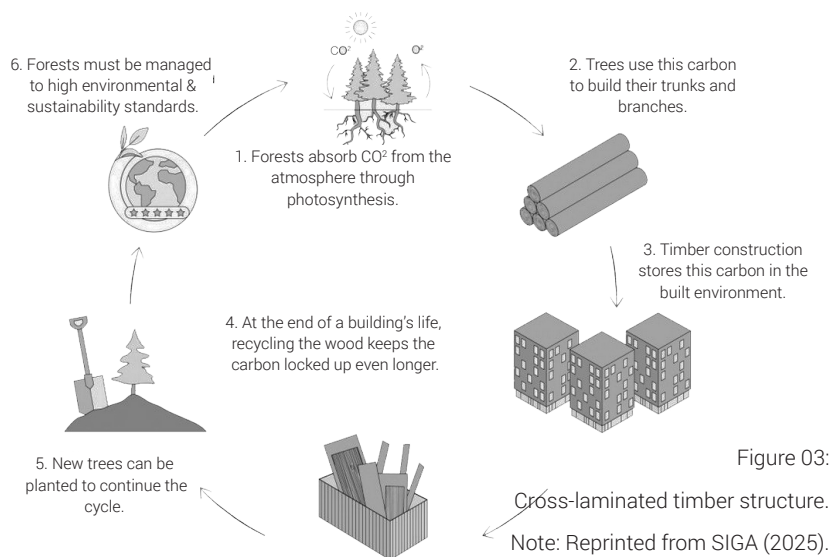
Flexibility and adaptability are key concepts in current architectural practice, particularly when it comes to hybrid building methods like the one investigated in this study (integration of prefabricated CLT modules onto existing concrete structures).

Accordingly, adaptability is the building's ability to undergo long-term structural changes that support changing functional, spatial, and socioeconomic demands with the least amount of disruption whereas flexibility is the ability to immediately reconfigure interior spaces to accommodate changing user needs. (Almourad et al., 2024)

Key architectural solutions that assist these attributes include open-plan layouts, movable walls, and multipurpose zones, all of which allow spatial reorganization without affecting the building's structural integrity. Additionally, by encouraging user involvement and providing social and economic advantages, the design of outdoor areas, like terraces and balconies that residents can customize, improves adaptation. (Smektała & Baborska-Narożny, 2022).

In hybrid CLT projects, where prefabricated timber pieces are naturally modular and easily reconfigurable, these spatial and functional solutions are particularly useful. These technologies present a viable foundation for establishing adaptive and flexible housing options that can meet emerging needs.

Sustainability – Certifications



Recent studies have extensively recognized the advantages of CLT for sustainability and the environment, especially in relation to its extended lifespan, lower carbon footprint, and energy efficiency.

Because of its long-term usage and minimal environmental impact,

CLT buildings are becoming more and more acknowledged as structural sustainable solutions (Younis & Doodoo, 2022).

During manufacture, CLT emits substantially less carbon dioxide than conventional materials like brick, steel, and concrete. Furthermore, because a significant amount of the energy utilized in the manufacture of CLT originates from sustainable sources such as wood byproducts, the energy used is significantly less than that of other materials. Mainly due to the fact that wood products can be recycled, reused, or used for energy production once a building reaches the end of its lifecycle (Younis & Doodoo, 2022).

Internationally, frameworks for evaluating a building's sustainability credentials are provided by standardized environmental classification systems like LEED (United States).

Researching certifications is highly relevant for this project as it not only guides the design and construction process towards sustainability but also positions the development within a growing market of environmentally conscious consumers and investors and the stakeholders (U.S. Green Building Council, 2025).

Leadership in Energy & Environmental Design (LEED)

In Greece one of the most renowned certifications is LEED (Leadership in Energy & Environmental Design). According to the official page of LEED certification, obtaining or upgrading a building to meet LEED standards requires compliance with specific criteria. The primary requirements for that include adherence to sustainability principles, energy efficiency, water conservation, indoor environmental quality, and the use of environmentally responsible materials. (U.S. Green Building Council, 2025).

These criteria ensure that buildings meet high-performance standards in terms of resource efficiency and environmental impact reduction:

- **Site selection:** This involves choosing the precise site for building construction and preserving, or even restoring, existing natural habitats and wildlife.
- **Location and transportation:** Transportation has a significant impact on CO² emissions and climate change. Proximity to existing public transportation also plays a role.
- **Water management:** The building's design and use should minimize water consumption, harvest rainwater, and optimize wastewater recycling.
- **Energy management:** Energy efficiency vital part of LEED certification. Implementation of passive design strategies based on climatic conditions, use of renewable energies, and establishment of control systems are important for LEED certification.
- **Indoor environmental quality:** Continuous monitoring of indoor air quality and effective ventilation are factors considered in the LEED framework.
- **Materials:** The use of durable, local, bio-sourced, and low environmental impact materials is encouraged.
- **Innovation:** This category rewards innovative approaches and creative solutions that go beyond standard certification requirements.
- **Local and regional priorities:** This encourages real estate projects to consider the environmental, social, and health priorities of the project's location.

LEED certification is structured into different levels based on the total points earned by a building. Each level reflects a commitment to sustainable construction practices, energy efficiency, and reduced environmental impact. The certification process encourages the integration of innovative design solutions to improve building performance and occupant well-being (U.S. Green Building Council, 2025).

The certification levels are as follows:

LEED Class	Points Required
Certified	40-49 points
Silver	50-59 points
Gold	60-79 points
Platinum	80+ points

The average cost of LEED certification for a 10,000 square meter building is between €6,000 and €7,500, depending on the facility's size, complexity, and desired certification level (U.S. Green Building Council, 2025). In Greece there are now approximately 285 LEED projects, even though not all of them have achieved complete certification. (U.S. Green Building Council, 2025)

Cross-Laminated Timber (CLT) provides various benefits that are consistent with LEED certification standards, making it an excellent alternative for sustainable building. Especially with prefabrication, CLT projects reduces waste and environmental disturbance onsite, and the materials thermal insulation boosts energy efficiency, supporting LEED's energy and atmosphere category. In addition, wood's materiality enhances interior environment and contributes to points in the indoor quality category.

Challenges & Barriers

As previously noted, the viability of the CLT building construction is established by comparing its benefits with the drawbacks. Evidence of CLT drawback could be found in an article that investigates real-world challenges observed during CLT building in the UAE (a region that shares several similarities with Greece). These barriers, identified through survey data and stakeholder interviews and can be classified into six primary categories: knowledge and awareness, economic restrictions, political constraints, material availability, social acceptance, and technological challenges. (Pilathottathil & Rauf, 2024)

Knowledge and awareness, are likely the most significant barrier, with 69.2% of responders (18 out of 26) identifying it as the key challenge. Many experts, including architects, engineers, and construction managers, have just a fundamental knowledge of the qualities and benefits of CLT. Misconceptions and skepticism are a key concern, with some participants believing that CLT is less durable, fire resistant, and has a shorter lifespan than concrete or steel. (Pilathottathil & Rauf, 2024)

Economic factors present another significant hurdle, with 50% of survey participants (13 out of 26) implying high initial costs as a deterrent to CLT adoption. These initial prices are currently quite more than traditional construction materials, attributed mostly to importation costs, limited local supply networks, and a lack of economies of scale in the local context.

Despite the potential for long-term savings in maintenance and energy efficiency, many developers and contractors prioritize short-term capital expenditures, making it difficult for CLT to compete with more established materials such as reinforced concrete and steel. (Pilathottathil & Rauf, 2024)

Regulatory challenges and municipal approval processes are major barriers to CLT adoption, with 38.4% of participants (10 out of 26) citing building code restrictions as an obstacle (Pilathottathil & Rauf, 2024). In southern countries, current building regulations do not have specific provisions for timber construction, unlike countries such as Canada, Austria, and Sweden, where International Building Codes (IBC) or Eurocode 5 provide frameworks for structural timber design. This lack of regulation discourages architects and developers from pursuing CLT projects, as obtaining approvals from municipal authorities and civil defense agencies remains a complex and uncertain process. (Pilathottathil & Rauf, 2024)

Material availability was identified as a key limitation of a total of 30.8% of survey respondents (8 out of 26). The UAE, in this case Greece, currently imports the majority of CLT panels from European countries, leading to longer lead times, high transportation costs, and environmental concerns related to shipping emissions. The reliance on imported CLT creates uncertainty in pricing and supply chain stability. (Pilathottathil & Rauf, 2024)

Cultural acceptance of CLT as a viable building material is another obstacle, with 23% of survey participants (6 out of 26) perceiving resistance to change as a major barrier. The UAE's construction industry, likewise Greece, has historically relied on reinforced concrete and steel, leading to a strong preference for conventional materials. Additionally, public skepticism regarding fire safety, strength, and maintenance of CLT buildings has slowed acceptance. Some professionals also expressed concerns about the lack of skilled labor and expertise in CLT construction. (Pilathottathil & Rauf, 2024)

Technological challenges are perceived only by 7.6% of participants (2 out of 26) as a significant barrier, but it remains an important factor. Concerns include fire resistance, moisture control, and acoustic performance of CLT buildings in hot and humid climates. Some participants believe that CLT may not be ideal for extreme weather conditions and as effective as concrete. (Pilathottathil & Rauf, 2024)

Overall, the adoption of CLT in construction, while promising, faces several challenges that hinder its widespread implementation, particularly in regions of the south like Greece.

To address these challenges, a multifaceted approach is necessary. Financial incentives, such as government subsidies, tax breaks, or investments in local CLT production, could overcome economic barriers by reducing upfront costs and fostering economies of scale. (Pilathottathil & Rauf, 2024). Structured knowledge is promoted through technical seminars, industry collaborations, and government campaigns would help counter misconceptions and enhance stakeholder understanding of CLT's environmental and structural advantages. The expansion of regulatory framework, aligned with international standards like Eurocode 5, could simplify approval processes and encourage CLT adoption (Pilathottathil & Rauf, 2024).

Additionally, investing in local CLT production facilities or exploring alternative sustainable timber sources would reduce dependency on imports, ensuring a more stable and cost-effective supply chain. Public awareness campaigns, demonstration projects, and educational workshops could shift cultural perceptions and highlight CLT's benefits, while further research and development (R&D) tailored to local climate conditions would address technological concerns and support regulatory acceptance. (Pilathottathil & Rauf, 2024).

Prefabrication

Wood is characterized by certain features, such as low weight and simple manufacturing, which make it suitable for the realization of prefabricated components for the construction industry. Moreover, computer-aided design and production applied to new timber technologies allow even higher quality standards to be reached and enhance possibilities for product customization, according to the specific needs of individual buildings (Borgström & Fröbel, 2019). Overall, modular construction proves to be more time-efficient than conventional construction, with 3D modular construction being the fastest approach due to its extensive off-site prefabrication. Accordingly 2D modular construction still relies on significant on-site assembly, nevertheless it offers considerable time savings compared to traditional methods. (Smyth, 2018)

The prefabrication process is especially advantageous for the construction process, based on aspects that are summarized in the following bullet points. (Abiri, Louis, & Riggio, 2019).

Quality

- Less storage areas (a reduced footprint could be a relevant issue in urban areas).
- Less teamwork and construction site disorder (materials, machinery, and workers) to be coordinated.
- Waste minimization (e.g., scraps reduction).

Time

- Higher installation efficiency within the production site.
- Time saved for storage procedures (e.g., insulation, cladding, etc.).

Cost

- Reduced cost of risks.
- Very short return on investment cost (m² available for sale in record time).

Risk

- Major safety for workers due to manufacturing in the production workshop.
- Minimization of weather variability-related risks.
- Lower probability of mistakes during work execution.
- Fewer contractors to cope with.

In conclusion, based on all the above, it is assumed that prefabricating CLT elements has significant advantages, particularly for tall and mid-range buildings. Off-site fabrication reduces construction costs by streamlining installation, cutting labor expenses, and minimizing on-site work. Prefabrication accelerates construction schedules, with larger panels requiring fewer handling operations. It also improves site organization, enhances worker safety, and provides immediate protection against weather exposure. Optimizing panel dimensions and fastening systems could enhance efficiency of CLT construction. (Abiri, Louis, & Riggio, 2019).

Construction process – details



Construction methods vary significantly in efficiency. Conventional construction tends to be the most time consuming due to the extensive on-site assembly and material preparation required. While minor tasks like frame installation are relatively quick, the overall process involves several stages, including material loading, transportation, unloading, and a lengthy on-site assembly phase. (Smyth, 2018).

On the other hand, 2D modular construction offers improved efficiency by prefabricating panels in controlled manufacturing environments. This approach streamlines the process, significantly reducing the total construction duration. Panels are produced swiftly, then transported, unloaded, and assembled on-site with far less time (Smyth, 2018).

Figure 04: Building lifespan and environmental impact of timber construction./ Note: Reprinted from Puuinfo (2015).

Even more efficient method could be considered the 3D modular construction. By assembling volumetric modules off-site before transportation, this method minimizes the need for extensive on-site work. As a result, it substantially reduces labor demands and installation time, automating the overall construction process. (Smyth, 2018).

Worksite Planning, Transport, and Installation

Efficient worksite layout planning is essential for maximizing CLT transportation and installation. CLT panels are usually packed vertically for short-distance transportation or stacked horizontally with wooden supports. Crane verification, load-bearing roadways, and adherence to specific transport licenses are necessary for ensuring uninterrupted transport (Stora Enso, 2020).

Panels must be shielded from moisture exposure on-site, and if an immediate installation is not feasible, they should be stored in the interim under plastic sheets or tarps. Screw-fastened hoists simplify installation, and lifting points are thoroughly tested to prevent damage. Proper joint sealing using polyurethane foam, expanding sealing strips, EPDM rubber seals, and elastic sealing compounds ensures airtightness, moisture resistance, and structural integrity (Stora Enso, 2020).

Cost and Efficiency of Off-Site Prefabrication

Costs are greatly decreased by off-site CLT prefabrication, especially when labor costs associated with handling, installation, and transportation are minimized. Optimized panel dimensions result in significant cost savings by lowering the need for scaffolding and material handling. Heavy-duty connections that are preinstalled simplify the fastening process and significantly save costs (Brandt et al., 2019).

CLT Construction and Structural Design Considerations

CLT structures necessitate careful structural design to maximize load-bearing capacity, fire resistance, and environmental sustainability. According to Swedish CLT handbook, CLT floors and walls are typically thicker than concrete, but their exterior walls can be smaller while yet having a similar thermal efficiency. In order to account for differential settling, proper joint design is crucial, especially when attaching CLT to concrete facades, elevator shafts, or stairwells (Swedish Wood, 2019).

Moisture Protection in CLT Construction

Given the organic nature of CLT, moisture management is critical for preventing structural damage and microbial growth (Schmidt & Riggio, 2019). Buildings must be built to avoid moisture buildup in order to maintain structural integrity and hygienic conditions. To reduce exposure, CLT components must be protected during manufacturing, shipping, and installation (Saint-Gobain Sweden AB, 2020). To hinder water infiltration during construction, protective tents or temporary rain barriers could be used. In general, rapid installation, weather protection, and controlled internal heating are required to maintain ideal moisture levels (Swedish Wood, 2019).

Key Soundproofing Challenges in CLT Buildings

One of the key challenges in Cross-Laminated Timber (CLT) structures is controlling low-frequency sounds, which are more difficult to insulate than mid and high frequency noises. Due to the lightweight nature of CLT, such sounds are more audible and easily transmitted, making effective sound insulation essential. (Saint-Gobain Sweden AB, 2020).

Compared to heavier materials like concrete, CLT frameworks are more susceptible to flank transmission, which is described as the transfer of sound through connected structural elements like walls or floors (Saint-Gobain Sweden AB, 2020).

Key areas requiring attention in wooden building acoustics include:

Footstep Impact: The lightweight character of CLT amplifies footstep noise. Adequate insulation within floor assemblies or joists is often necessary to meet acoustic performance standards (Lin, Yang, & Tsay, 2021).

Sound Transmission at Junctions: Connections and junctions can be weak points for sound leakage, necessitating precise design and execution.

Tenant Awareness: Occupants should be informed of the different acoustic characteristics of CLT buildings to manage expectations.

The Swedish Building Regulations (BBR) define specific sound insulation requirements for various building types. For residential buildings, the required insulation range spans frequencies from 50 to 3150 Hz (Saint-Gobain Sweden AB, 2020).

Fire Resistance of Cross-Laminated Timber (CLT) in Housing Buildings

Fire resistance in buildings depends on the interaction of structural components rather than the properties of individual materials. In CLT construction, understanding fire behavior is crucial to prevent fire spread and maintain structural integrity under high temperatures (Schmid et al., 2019). When designed in accordance with regulatory classifications, CLT buildings can achieve fire performance comparable to that of conventional structures. (Saint-Gobain Sweden AB, 2020).

Construction overview

Based on the theoretical framework, the suggested structural detailing for a hybrid structure, as presented in this thesis, focuses on key objectives (Wahlstrøm, 2020).

Base Connection (Floor to Concrete Slab):

- Steel plates or anchor bolts embedded in the concrete slab.
- CLT panels are fixed with shear connectors or expansion anchors.
- EPDM gasket or rubber pads for acoustic and moisture separation.

Wall to Column Connection:

- Steel brackets bolted into the concrete column and screwed into the CLT panel.
- Slotted holes for minor tolerances in movement.
- Fire-resistant sealants in gaps.

Beam to CLT Floor Connection:

- CLT floor panel rests on steel ledger angles fixed to the concrete beams.
- Shear connectors or dowel plates prevent horizontal movement.
- A thin compressible gasket prevents sound transmission.

Lateral Stability:

- Diagonal steel braces or stiff CLT shear walls resist lateral loads.
- Hidden dowels or metal fasteners between panels improve rigidity.

Thermal & Moisture Protection:

- A waterproof membrane between CLT and concrete to prevent moisture transfer.
- Thermal insulation panels on the exterior of the CLT module.

Construction methodology

Foundation and existing concrete frame evaluation, followed by the pre-fabrication of CLT modules. Once fabricated, the installation of CLT modules takes place, ensuring proper placement. This is followed by connection and sealing to secure the structure. The process concludes with quality control and testing to verify compliance with required standards (Jeong, 2024).

Foundation & Concrete Frame evaluation:

In the researched scenario, the reinforced concrete foundations, columns, and beams are already built, so the only process involved is examining their current state and the possibility of some restoration.

Pre-Fabrication of CLT Modules:

- Off-site fabrication of CLT wall and floor panels.
- Factory cutting of openings (doors, windows, service routes).
- Application of fireproof coatings, insulation, and finishes.

Installation of CLT Modules:

- Delivery and on-site lifting using cranes.
- Positioning of base CLT panels and securing to concrete with anchor bolts.
- Sliding of vertical CLT walls, upon the floor panels with rails and stabilized them with temporary bracing.
- Installation of CLT walls and floors with steel ledger supports and metal breaks on the rails.

Connection and Sealing:

- Install metal brackets, screws, and dowels at all junctions.
- Apply acoustic & fire-rated sealants in all gaps.
- Ensure waterproofing membranes are intact.

Service Integration & Finishes:

- Routing for MEP (mechanical, electrical, plumbing) through pre-cut channels in CLT (100mm space is free under the floor because of the gap between the rails and the floor slabs).
- Apply internal finishes such as gypsum board or exposed timber coatings.
- Exterior cladding or insulation layers added where needed.

Quality Control & Testing:

- Inspect the structural integrity of joints and connections.
- Conduct moisture content tests in CLT elements.
- Ensure fire-stopping measures are correctly installed.

Based on several technical brochures and industrial references a good combination of structural details for the proposed hybrid project would be those that follow: (Borgström & Fröbel, 2019; Gobain Sweden AB, 2020).

Exterior walls (ISOVER PLUS+)

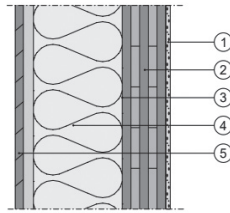
Wooden façades on façade-bearing insulating systems



Fire resistance ²
(inside and out)
Façade fire

REI
SP Fire 105

REI 60 ($\mu fi=60\%$)
REI 90 ($\mu fi=40\%$)
Approved ¹



1. 12.5 mm Gyproc GNE 13 Normal
2. 120 mm CLT element
3. 0.2 mm ISOVER Vario[®] Xtra
4. 220 mm ISOVER PLUS[®] Board 32 between
- 245 mm ISOVER PLUS[®] Stud 1
5. 22 mm Wooden façade Moelven Thermowood

Why this solution:

- Combines excellent thermal and acoustic insulation with a wooden exterior façade, fitting your preference for wooden surfaces.
- Suitable for limited space due to its efficient use of insulation thickness.

Partition wall (GYPROC GFE AND ISOVER CAVITY WALL BOARD CLT 100 MM)

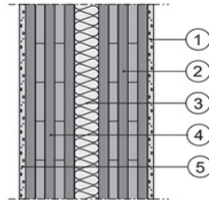
Apartment partitioning



Fire resistance &
load utilisation

REI /
 μfi (%)
(3 layers)

REI 60 /
 μfi 60%



1. 15.4 mm Gyproc GFE 15 Protect F[®]
2. 100 mm CLT element
3. 100 mm ISOVER Cavity Wall Board 32
4. 100 mm CLT element
5. 15.4 mm Gyproc GFE 15 Protect F[®]

Why this solution:

- Provides high sound insulation, which is critical for apartment living spaces.
- Fire-resistant and lightweight, suitable for a hybrid structure.

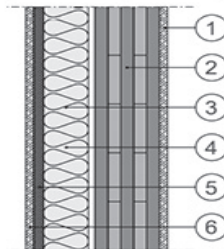
Wet Rooms (GLASROC H OCEAN, PLYWOOD, GYPROC ER WITH ISOVER PIANO CLT 100 MM)



Fire resistance &
load utilisation

REI /
 μfi (%)

5 Layers:
REI 60/ $\mu fi=50\%$ /
REI 60 ($\mu fi=50\%$)



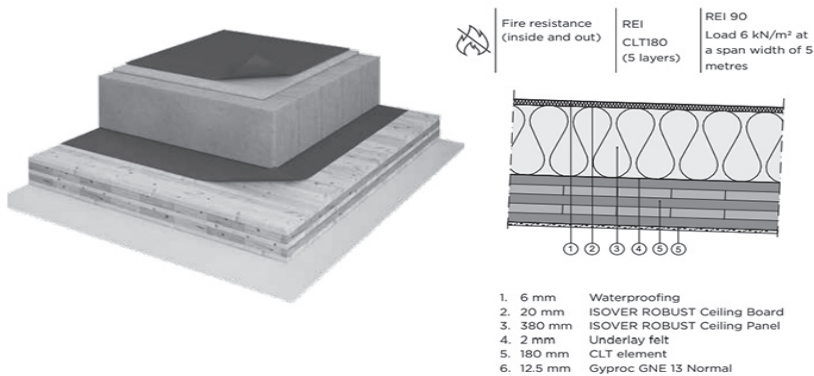
1. 12.5 mm Glasroc H GH0 13 Ocean[®]
2. 100 mm CLT element
3. ≥ 10 mm Air gap
4. 70 mm Gyproc ER 70 with ISOVER Piano[®] Sound Board, centre distance 450
- 70 mm Structural plywood
5. 15 mm
6. 12.5 mm Glasroc H GH0 13 Ocean[®]

Why this solution:

- Designed for wet rooms, offering moisture resistance and sound insulation.
- Lightweight and compatible with CLT modules.

Roofs (ISOVER ROBUST CEILING PANEL)

Exterior insulation for low-pitched roofs

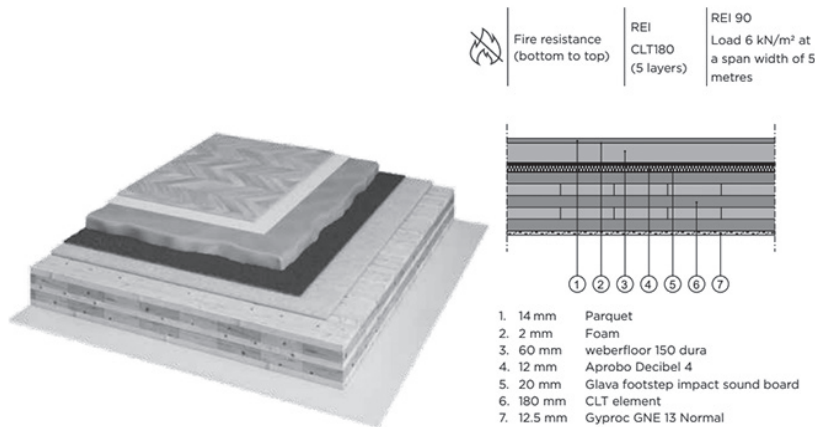


Why this solution?

- Offers superior thermal insulation and fire resistance.
- Compatible with CLT modules and provides a clean interior finish.

Intermediate Floors

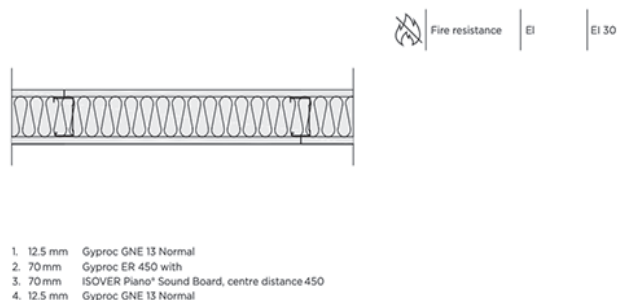
(SAINT-GOBAIN SILENT FLOOR® WEBER FLOOR SCREED, APROBO DECIBEL AND SAINT-GOBAIN GLASS WOOL)



Why this solution?

- Provides excellent sound insulation for floors, critical for multi-story apartments.
- Includes a wooden parquet surface, aligning with your preference for wooden interiors.

Non-Load-Bearing Partition Walls (GYPROC GNE AND GYPROC ER WITH ISOVER PIANO)



Why this solution:

- Lightweight and easy to install in a condensed space.
- Provides good sound insulation for non-load-bearing walls.

Figure 05 -10: Structural detail diagrams for floors, partitions, and insulation systems.
Note: Reprinted from Saint-Gobain (2025). Copyright 2025 by Saint-Gobain.

PROJECT DESIGN

Site analysis

Design references

Diagrams - Details

A Synthesis of Swedish and Greek Housing Ideals

Site analysis

Karaiskaki Square is a central urban area in Athens with notable characteristics. The wider area spans approximately 87.4 square kilometers, with an average elevation of 70 meters above sea level (Makrakis, 2006).

The square is located in the Metaxourgeio neighborhood, historically a working-class district that declined in the late 20th century but is now undergoing urban redevelopment (Makrakis, 2006).

Athens has a high population density of about 17,040 people per square kilometer, reflecting its mixed residential, commercial, and cultural landscape. (World Population Review, 2024)

As Greece’s economic hub, Athens’ economy spans finance, commerce, tourism, and services. Karaiskaki Square, in particular, hosts numerous businesses, hotels, & eateries, contributing to its vibrant commercial activity. (Mavratzas, 2008)



Figure 11:
Athens, Greece – Poster print.
Note. Adapted from Designer Map Art (n.d.).
Edited by the author.

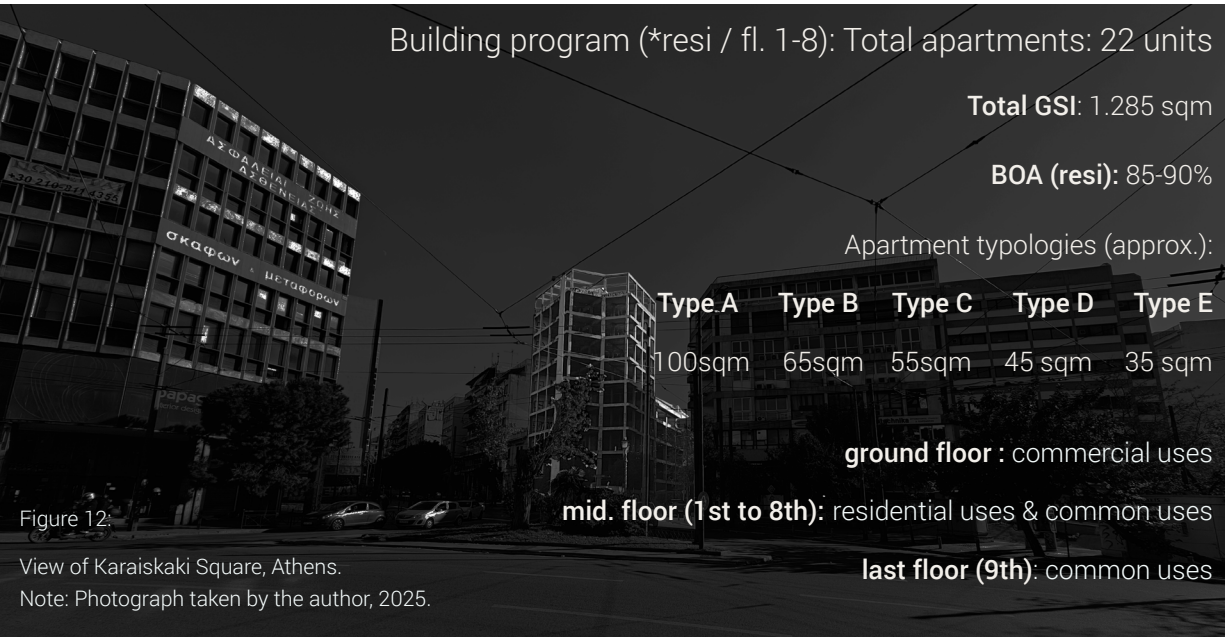


Figure 12:
View of Karaiskaki Square, Athens.
Note: Photograph taken by the author, 2025.



Existing situation

Deligiorgi 55, Athina 104 37,
Greece

37.9 84930, 23.722302

Key Location Analysis Factors:

- **Accessibility:**

The area is well-connected to the rest of Athens, with the Metaxourgeio metro station on Line 2 providing easy access to public transportation.

- **Cultural Significance:**

Metaxourgeio has emerged as a hub for artists and creatives, hosting numerous galleries, theaters, and cultural events, particularly around Avdi Square

Figure 13:

Site and existing building condition

Note: Photograph taken by the author, 2025.

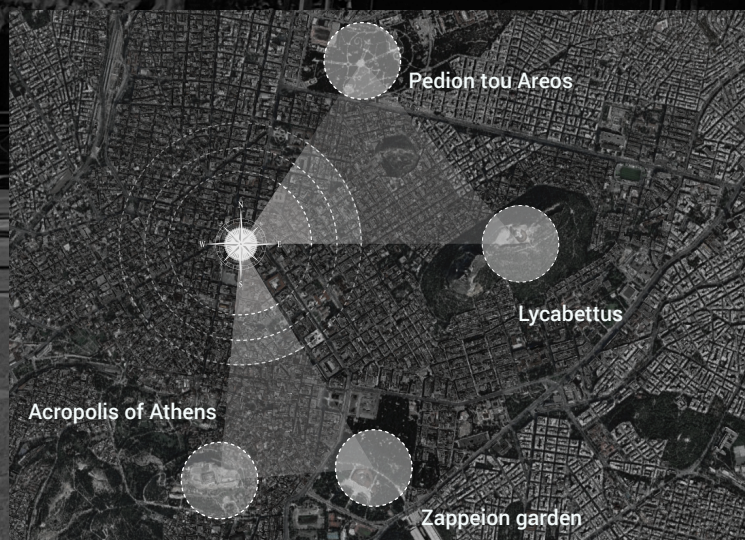


Figure 14: Zoom-out visibility map, Athens.

Note: Adapted from Google Earth (2025) and edited by the author.

• **Economic Activity:**

The influx of cultural venues has spurred economic growth, attracting cafes, restaurants, and boutique businesses, contributing to the area's gentrification.

• **Environmental factor:**

Athens, including areas like Metaxourgeio, experiences the urban heat island effect, leading to higher temperatures compared to surrounding rural areas.

In general, the city experiences a hot-summer Mediterranean climate, characterized by hot, dry summers and mild, moderately rainy winters. (Climate-Data.org, 2024)



Figure 16:

Front side elevation of the building, Athens.

Note: Photograph taken by the author, 2025.



Figure 17:

Back side elevation of the building, Athens.

Note: Photograph taken by the author, 2025.



Figure 18:

Right side elevation of the building, Athens.

Note: Photograph taken by the author, 2025.



Figure 15: Zoom in map - vivability map. edited by the author. Adapted from Google Earth, 2025

Existing building

Despite the limited data with public access to engineers some information regarding the under-examination property is the following. The plots that consist the whole plot are located at the intersection of Deligiorgi & Agiou Konstantinou streets in central Athens, namely plot A & plot B as documented in the official title deeds. The unified property was originally constructed with the intention of operating as a hotel, although it is currently abandoned and under consideration for adaptive reuse. The architectural presentation and site analysis suggest the potential transformation of the building into a mixed-use complex comprising residential units and commercial spaces, in alignment with contemporary urban regeneration strategies.

(Chronis, 2020a, 2020b; Hellenic Cadastre, 2024a, 2024b, 2024c, 2024d; Municipality of Athens, 2024).

plot A:

- address: Deligiorgi 61 & Ag. Konstantinou
- plot Area: 190 m²
- built Surface: 1,488.67 m²
- number of Floors: 9

plot B:

- address: Deligiorgi 34–36
- plot Area: 264 m²
- built Surface: 965.52 m²
- number of Floors: 6

Ownership: Atlas Estia (Private Capital Company)

Acquisition Date: August 2020

Legal Status: Full ownership through purchase

Architectural Features

- Ground floor includes a covered space
- Basement (unknown – from the inspection seems to be absent)
- Typical floors suggest a modular layout, adaptable to residential or commercial use
- Due to lack of original permit documents, all existing plans were reconstructed through on-site measurement & visual inspection

Architecturally, the existing building is composed of two distinct volumes, one of regular geometry and another of irregular, as illustrated in the corresponding diagrams. Several challenges are anticipated in the context of the building's future redevelopment. Notably, any structural expansion of the existing framework will require a new building permit. Furthermore, given the building's prolonged abandonment, a comprehensive structural evaluation is necessary to determine the condition and performance of the existing loadbearing system, especially the reinforced concrete framework.

From a design and regulatory perspective, a further consideration is to be anticipated from planning authorities regarding the use of timber-based construction, as it remains relatively unfamiliar within the existing architectural typology of the surrounding urban fabric. From a structural standpoint, any intervention must respect the integrity of the existing framework, particularly the beams and columns, which should remain unaltered to preserve loadbearing capacity. This necessitates that any new design should be developed to coexist with the existing structure, followed by a complete structural assessment.

(Chronis, 2020a, 2020b; Hellenic Cadastre, 2024a, 2024b, 2024c, 2024d; Municipality of Athens, 2024).

Zoning & Urban Regulations:

Urban Zone: Central Area, Urban Sector C

Building System: Continuous

Total plot size: 454 sqm

Building Factor (GSI): 0.7

Floor coverage ratio (FSI): 3.0

Maximum Permitted Height: 18.5 m

Maximum Number of Floors: 4 (according to zoning)

*(that does not apply to existing structures)

Minimum Plot Dimensions for Development:

200 m² with 10 m frontage

112.5 m² with 6 m frontage

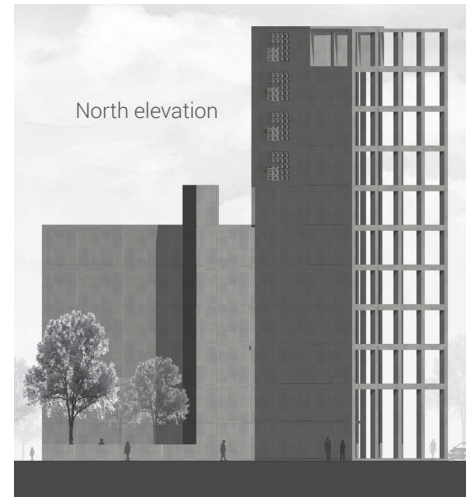
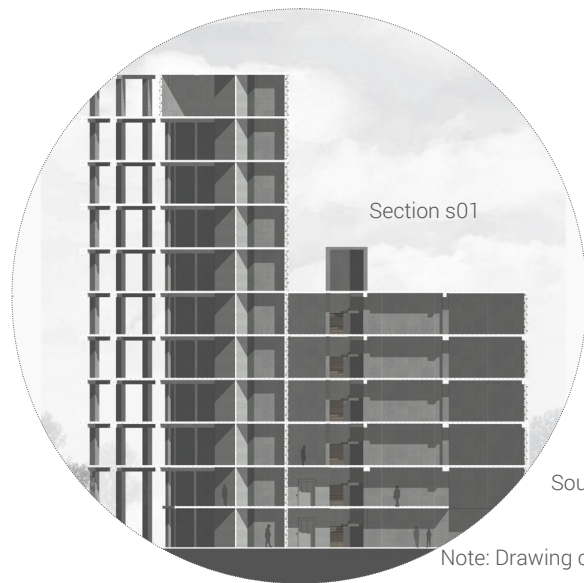


Figure 19:
Existing
South - East elevation &
Section s01 (1:100).

Note: Drawing created by the author

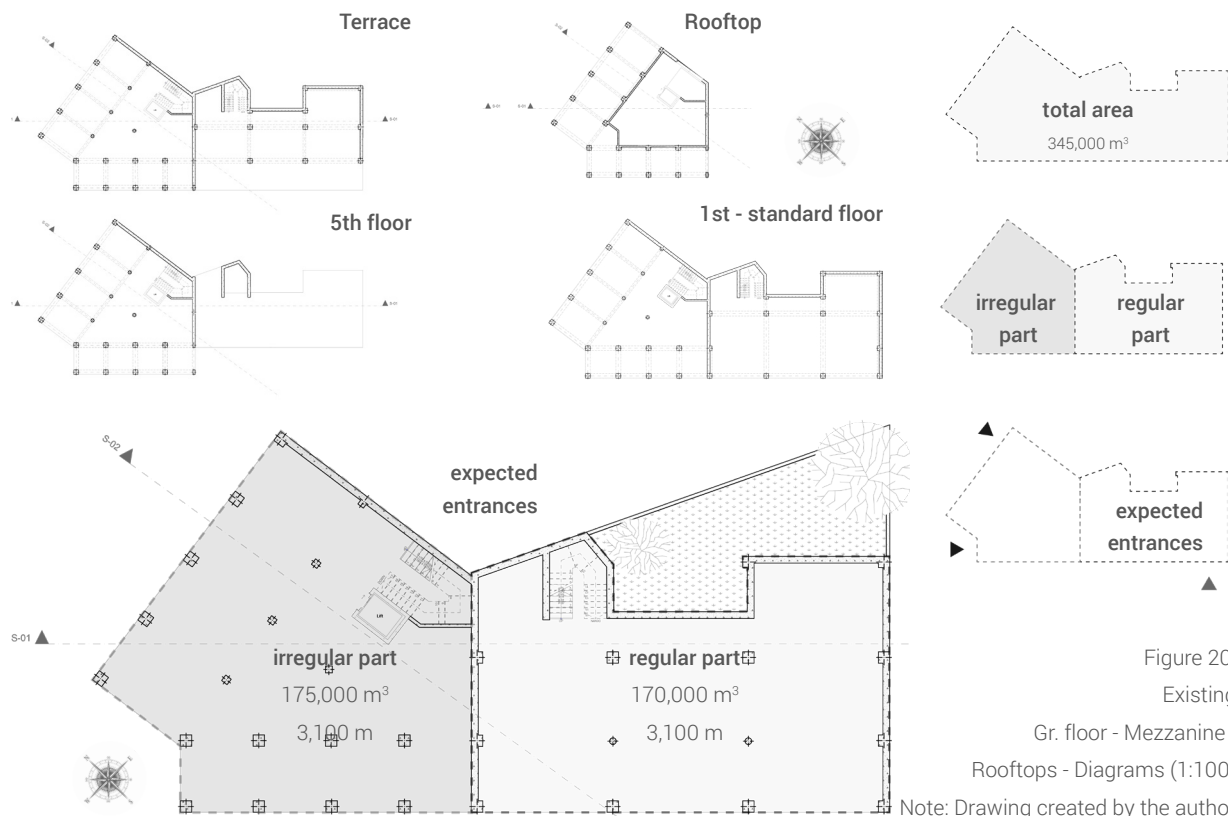


Figure 20:
Existing

Gr. floor - Mezzanine -
Rooftops - Diagrams (1:100)

Note: Drawing created by the author

Environmental studies

The average annual temperature in Athens is approximately 17.5°C. Monthly average temperatures range from about 10°C in January to 29°C in August.

(Climate-Data.org, 2025)

Temperature:

- Annual Average: Approximately 17.5°C.
- Monthly Averages: Temperatures range from about 8.2°C in January to 27.7°C in July.

Precipitation:

- Annual Total: Approximately 378 mm of precipitation falls annually.
- Monthly Averages: Rainfall varies throughout the year, with December being the wettest month, averaging 60 mm of rainfall.

Snowfall:

- Occurrence: Snowfall in Athens is rare but possible during the winter months.

Wind:

- Average Wind Speed: Varies throughout the year, with higher speeds typically observed during the summer months due to the Etesian winds, which are prevalent from May to October, peaking in July and August.

Sunshine:

- Summer Months: Athens enjoys long hours of sunshine during the summer months. In July, typically offers around 12 hours of sunshine per day.

Seasonal Overview:

- Summer (June to August): Hot and dry, with average daily highs reaching up to 32.8°C in July.

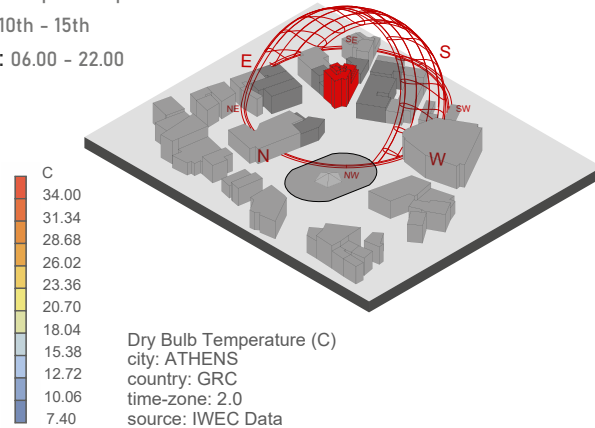
- Winter (December to February): Mild and moderately rainy, with average temperatures around 8.2°C in January

solar path

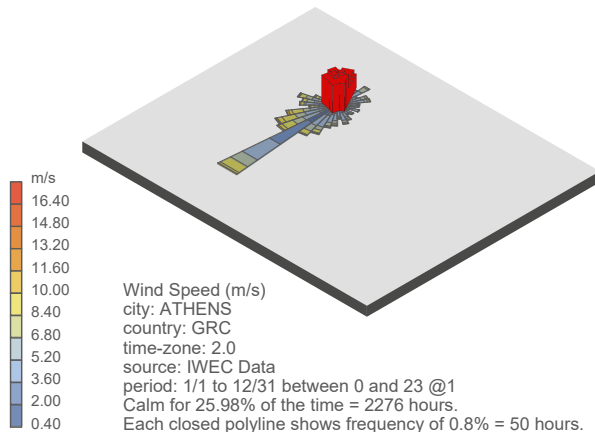
Period: April - September

Day: 10th - 15th

Time: 06.00 - 22.00



wind rose

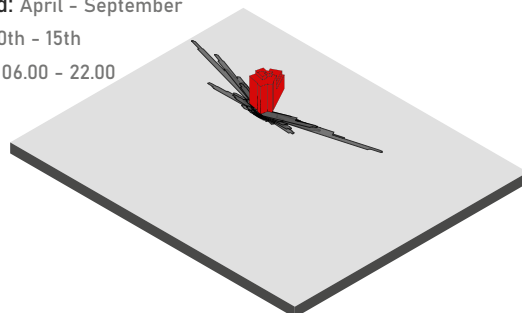


shadows

Period: April - September

Day: 10th - 15th

Time: 06.00 - 22.00

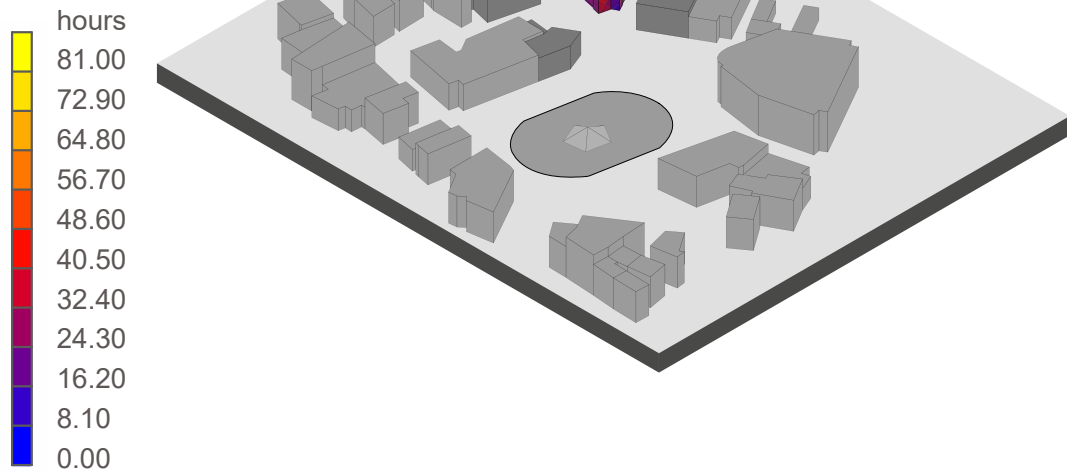


direct sun hours

Period: April - September

Day: 10th - 15th

Time: 06.00 - 22.00



incident radiation

Period: April - September

Day: 10th - 15th

Time: 06.00 - 22.00

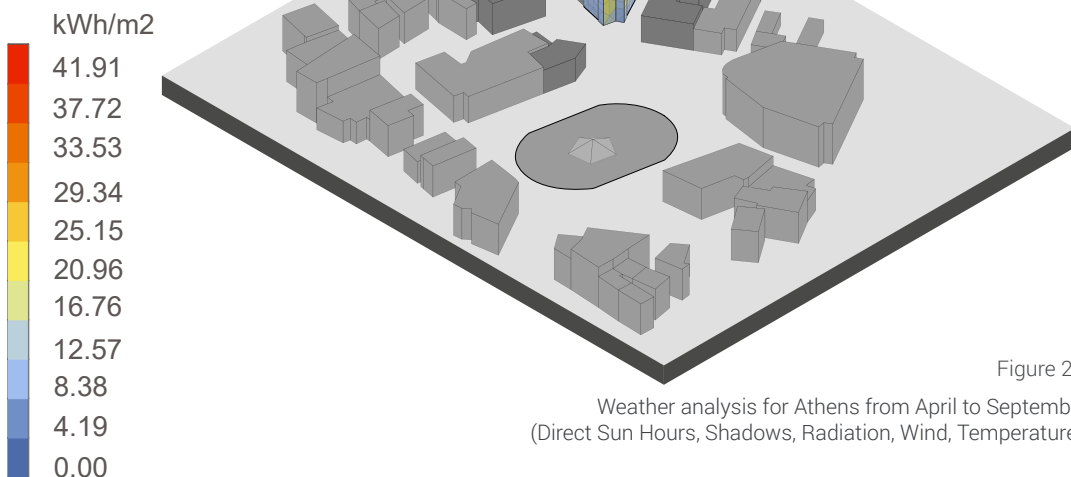


Figure 21:

Weather analysis for Athens from April to September
(Direct Sun Hours, Shadows, Radiation, Wind, Temperature).

Note: Diagram created by the author.

These climatic conditions make Karaiskaki Square and the broader Athens area suitable for outdoor activities for much of the year. (Holiday Weather, 2025) Spring (March to May) and autumn (September to November) offer particularly favorable weather, with moderate temperatures and limited rainfall, making them ideal periods for tourism and outdoor events. (Ferrante et al., 2020)

Reference projects/ Case studies

Including reference projects and case studies in this thesis is critical for proving CLT's practicality in Athens, encouraging innovative design solutions, and allowing for comparative analysis with established techniques. They establish CLT as a flexible, affordable, and sustainable urban regeneration option by bridging theory and practice by recording design procedures, construction difficulties, and outcomes (Fublis, 2023). For the purposes of this academic writing the following reference projects were examined, providing important assumptions:

- A. ***Dortheavej Residence/ 66 affordable residences in Copenhagen/ BIG***
- B. Woody M Buildings Tivoligasse/ Freimüller Söllinger Architektur
- C. De Warren project/ CLT Affordable Housing Build including 36 apartments/ Natrufied Architecture

Project presentation:



Figure 22: 04_BIG_DK02_Dortheavej Residence.

Note: Reprinted from Hjortshøj (n.d.).



Figure 23: 01_BIG_DK02_Dortheavej Residence.

Note: Reprinted from Hjortshøj (n.d.).



Figure 24: Dortheavej Residence.

Note: Reprinted from BIG - Bjarke Ingels Group (n.d.)

Key assumptions:

Project location: **Denmark - Copenhagen**

- It creates five-storey, 66 new homes for low-income residents ranging between 60 to 115 sqm in area.
- Each one has 3.5-metre-high ceilings, full-height windows, south-facing balconies and outdoor terraces
- Long wooden planks cover the facade on all sides, highlighting the modules.
- Stacking the modules to create between spaces
- The creation of much-needed affordable housing and public space retains the site's existing pedestrian passageways open and the adjacent green yard untouched
- On the sunny south side, balconies retract and add depth to the façade while on the northern side, the facade is even.
- The materials are kept very simple with wood and concrete in light colors dominating inside and out.
- The price per unit is about 10,000dkk a month for a 4-bedroom

Plans & diagrams:

Dortheavej Residence: site plan

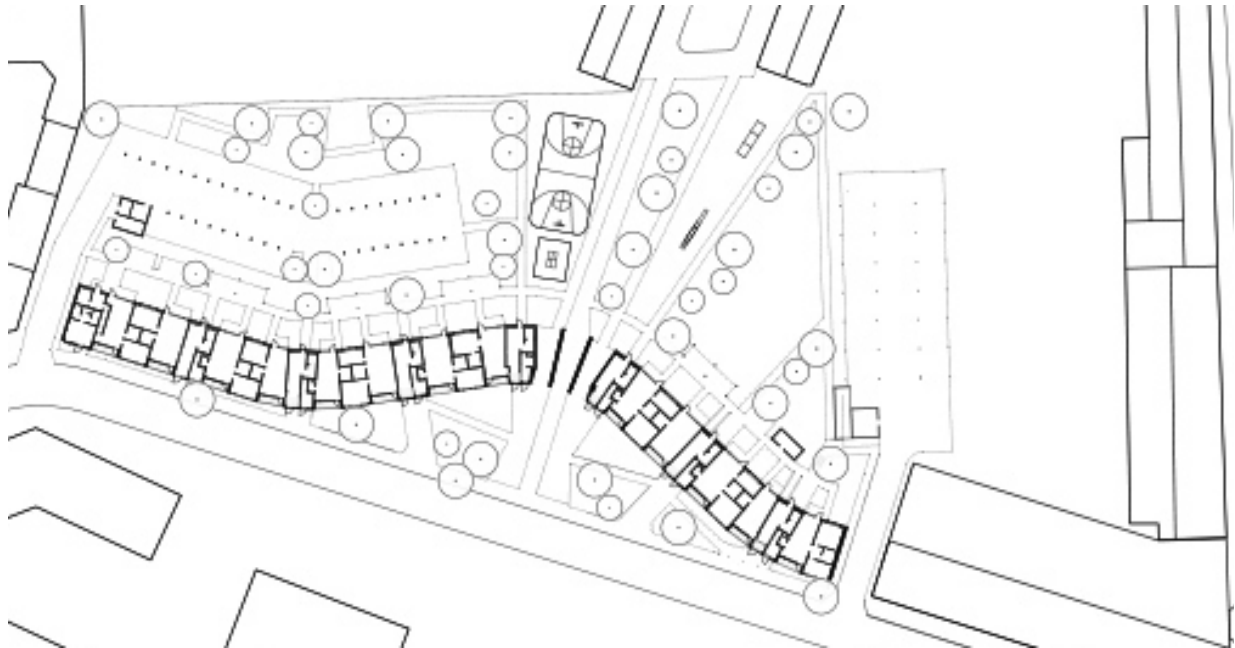


Figure 25: Dortheavej Residence – Site plan.
Note: Reprinted from BIG - Bjarke Ingels Group (n.d.).

Dortheavej Residence: section

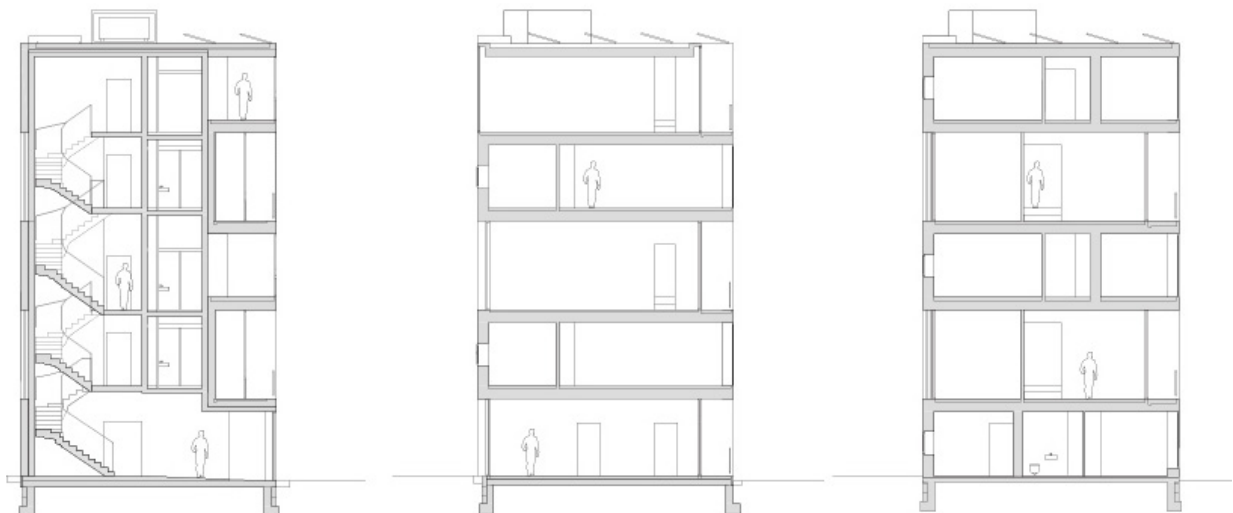
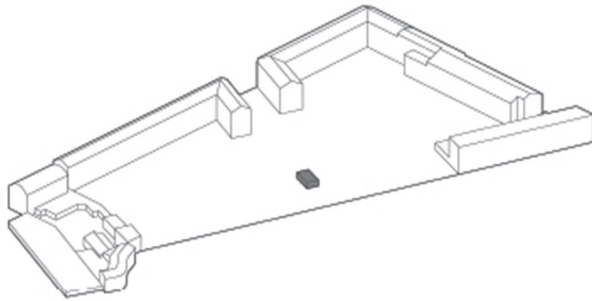


Figure 26: Dortheavej Residence – Section 1.
Note: Reprinted from BIG - Bjarke Ingels Group (n.d.).

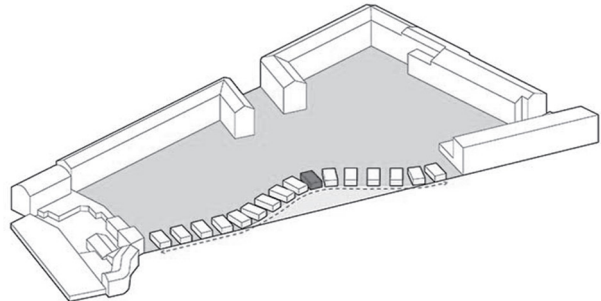
Plans & diagrams:

Dortheavej Residence: diagrams



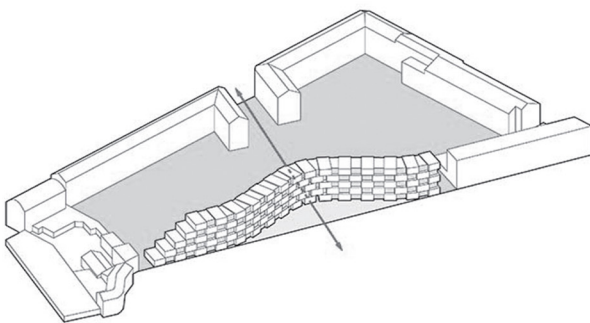
MODULE

The project is generated from a simple prefab structure



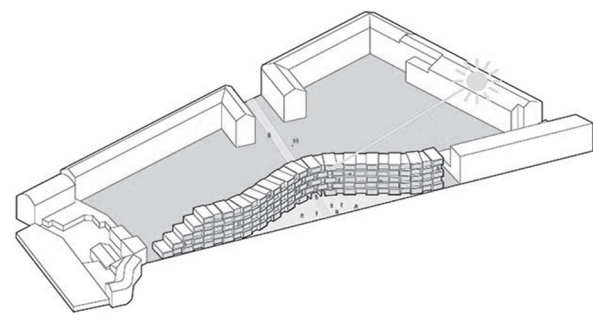
CURVE

The element is repeated along a curve, defining a courtyard for the urban block & introducing a public square towards the street



STACK

The element is stacked along the curve, creating interstitial spaces that face the yard & square



POROSITY

The building is raised to the height of its surroundings, with a passage at ground level that connects the yard & square

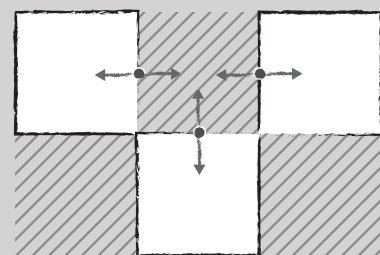
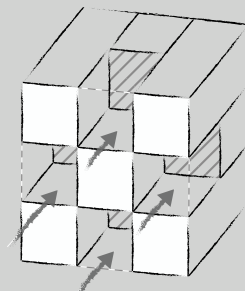
Figure 27-30: Dortheavej Residence – Conceptual diagrams.

Note: Reprinted from BIG - Bjarke Ingels Group (n.d.).

KEY design intakes - analysis diagrams:

--> void space

--> recede modules



- A. Dortheavej Residence/ 66 affordable residences in Copenhagen/ BIG
- B. *Woody M Buildings Tivoligasse/ Freimüller Söllinger Architektur***
- C. De Warren project/ CLT Affordable Housing Build including 36 apartments/ Natrufied Architecture

Project presentation:



Figure 31-34:
Tivoligasse housing project, Vienna.
Note: Reprinted from Freimüller Söllinger Architektur (n.d.),
photo by Kurt.

Key assumptions:

Project location: ***Austria - Wien, Tivoligasse 11***

- A five-story solid wood building built in an urban setting. Once a parking lot for 40 cars and a single-story supermarket transformed to a mixed-use residential building yielding 85 apartments with plenty of greenery and multiple connections and views throughout the structure.

- A plaza is formed where the staircase to the residential plateau, an entrance to the building, common rooms, and access to the ground-level bicycle garage is located.

- Innovative construction and materials. The outside walls are made of untreated planed wooden boards. In the apartments, the ceiling remains exposed to wood. The slab thicknesses vary, depending on the exact structural requirements, in order to save material.

- A total of 2,300 cubic meters of wood from domestic forests is used – the same amount of wood takes 40 minutes to grow back in Austrian Forests.

- Above the base, everything is made of prefabricated parts and assembled on-site, in order to ensure the dismantling of the building once necessary.

- The spaces between the buildings function as green open spaces with trees, bushes, and meadows for the residents and enable views between the neighboring buildings.

- The views of the new buildings are oriented in a north-south direction, with those of the neighbors in an east-west direction, ensuring maximum privacy for the residents.

Plans & diagrams:

Woody M Buildings Tivoligasse: footprints



Figure 35: Woody M Buildings, Tivoligasse – Footprint.
Note: Reprinted from Freimüller Söllinger Architektur (2023).

Woody M Buildings Tivoligasse: section

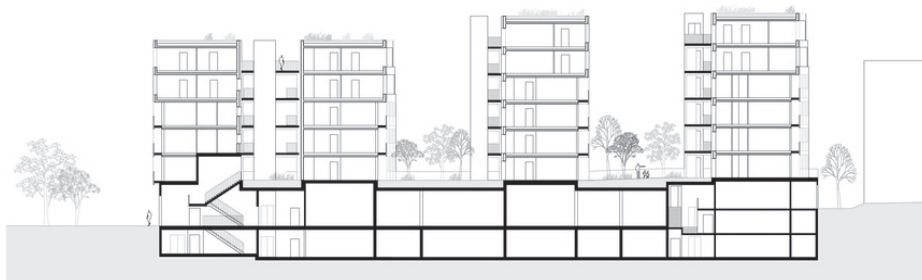


Figure 36: Woody M Buildings, Tivoligasse – Section.
Note: Reprinted from Freimüller Söllinger Architektur (2023).

Woody M Buildings Tivoligasse: elevation



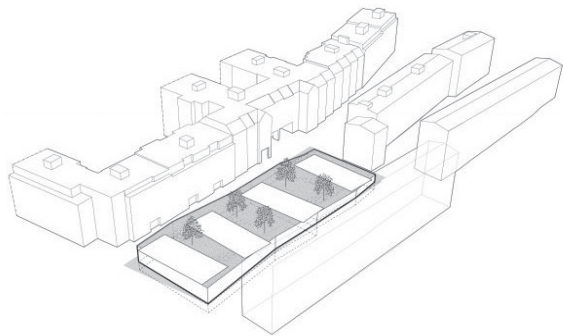
Figure 37: Woody M Buildings, Tivoligasse – Elevation North.
Note: Reprinted from Freimüller Söllinger Architektur (2023).

Plans & diagrams:

Woody M Buildings Tivoligasse: diagrams

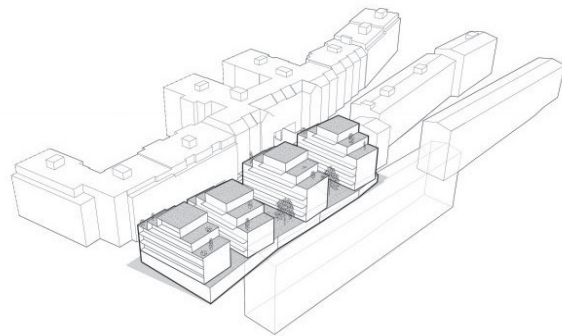
Figure 38: 123_TIV Konzept.

Note: Reprinted from Freimüller Söllinger Architektur (n.d.).



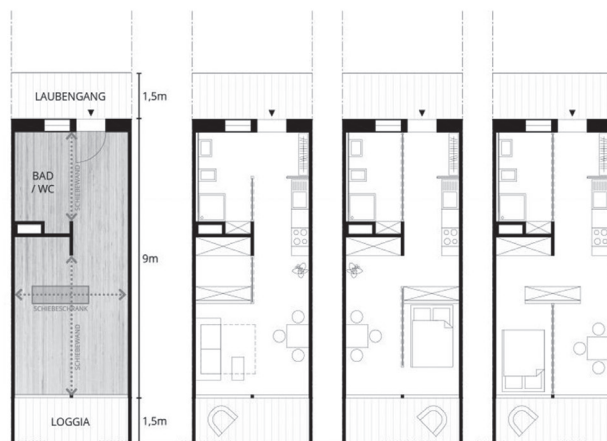
solid base

The solid base of the building does not fully utilize the building site. This gives the neighbors more space and at the same time creates a quiet deck for the new residents.



floated structure

On the upper floors, the building develops from the green deck into a versatile unit. Playfully placed, the wooden structures form a site-specific ensemble with numerous exciting spatial properties.



Scenario 1.

Scenario 2.

Scenario 3.

open floor plan open floor plan open floor plan

One floor plan-many alternatives

The basic type has numerous options for customization in a small space. Movable cupboard and wall elements combined with a targeted overlay of functional areas make the apartment flexible and open for temporary use depending on needs and time of day.

The wooden construction, which is also visible in the interior, creates a warm living atmosphere for the diverse residents.

Figure 39: 1321_TIV Konzept.

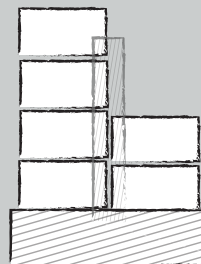
Note: Reprinted from Freimüller Söllinger Architektur (n.d.).

KEY design intakes - analysis diagrams:

--> module stacking

--> inner connectivity

--> spacial arrangement



- A. Dortheavej Residence/ 66 affordable residences in Copenhagen/ BIG
- B. Woody M Buildings Tivoligasse/ Freimüller Söllinger Architektur
- C. **De Warren project/ CLT Affordable Housing Build including 36 apartments/ Natrufied Architecture**

Project presentation:

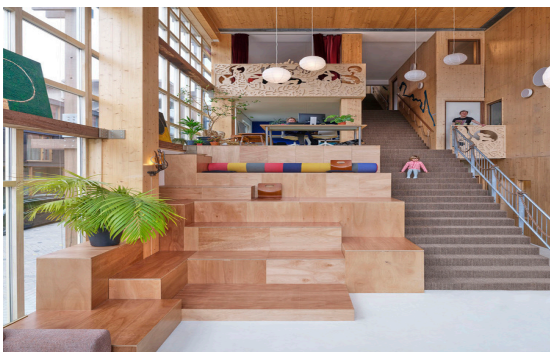
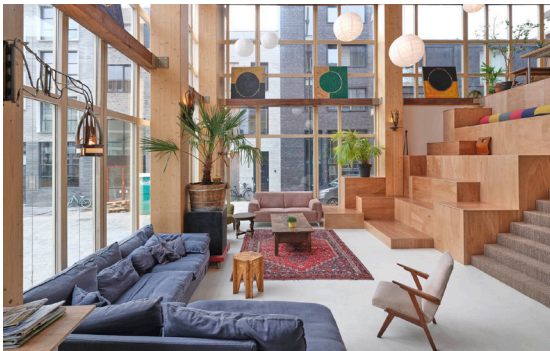
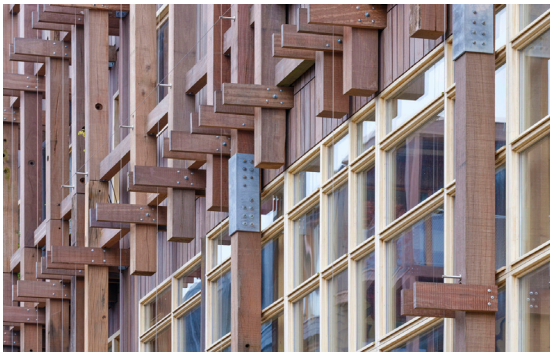


Figure 40 - 43:
De Warren, Amsterdam – Exterior & interior Note:
Reprinted from Musch (2023).

Key assumptions:

Project location: **Netherlands - Amsterdam**

-The project consists of 36 apartments for social and affordable rental housing, with a focus on sustainable and collective living.

The project includes 800 m² (30% of all spaces) of communal spaces. These spaces are organized around the “Machu Picchu” staircase, which connects all floors and encourages social interaction among residents.

-The building’s exterior cladding is made from reused retaining walls of azobe wood, and the façade incorporates planters that use rainwater from the green roof.

-The building generates its own energy through “energy piles” that act as heat exchangers and a heat pump, and solar photovoltaic panels on the roof.

-The total of 330 m³ of wood that was used, which has stored more than 300 tons of CO₂ during its lifetime. This is equivalent to approximately 200 years of emissions from the average car in the Netherlands.

-The ‘mikado’ front facade for balconies and a nature - inclusive approach (with planters that use rainwater from the polder roof) is made of recycled bollards (Basralocus).

-It was decided not to connect to the local heat network, but to keep heat generation in-house. Due to the ground conditions, piles of 30 meters had to be used. These piles have been transformed into ‘energy piles’.

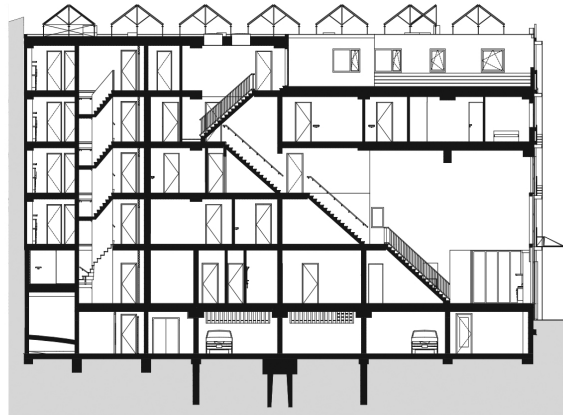
By adding hoses through the piles as a heat exchanger and a heat pump, ground heat (or cooling) is extracted and distributed throughout the building. The roof is of course reserved for PV panels.

Plans & diagrams:

legend:

1. communal kitchen & living room
2. studio flat
3. music studio
4. multipurpose room
5. garden
6. co-working space
7. two-bedroom flat
8. three-bedroom flat

De Warren project: section A'-A



De Warren project: footprint gr. floor-1st floor



Figure 44-46: De Warren, Amsterdam – Footprints & section.

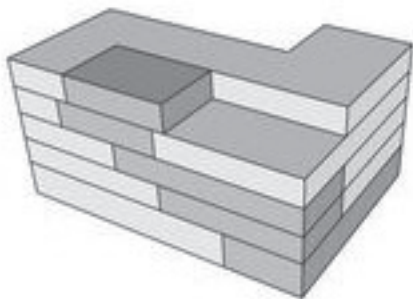
Note: Reprinted from Musch (2023).

Plans & diagrams:

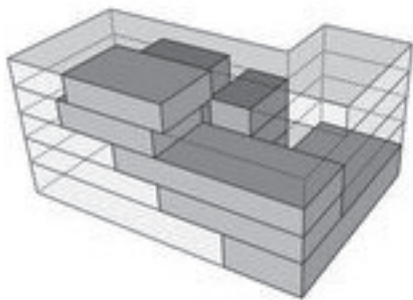
De Warren project: diagrams



phase 1.
collective space
integrated through the
building



phase 2.
origin of the 'Machu
Picchu connecting
kitchens to collective
space



phase 3.
collective space
integrated through
building



phase 4.
adding nature-inclusive
facade

KEY design intakes -
analysis diagrams:

- > green facade
- > ground floor configuration
- > ground floor facade

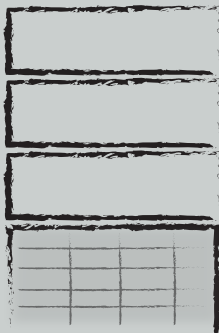
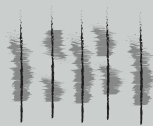
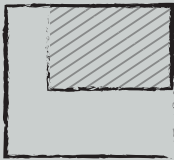


Figure 47: De Warren, Amsterdam – Concept diagram.
Note: Reprinted from Musch (2023).

PROJECT DESIGN

Renders

Footprints - Elevations - Sections

Diagrams - Details

A Synthesis of Swedish and Greek Housing Ideals

Exterior render

volumetric studies

- view from Karaiskaki sq.

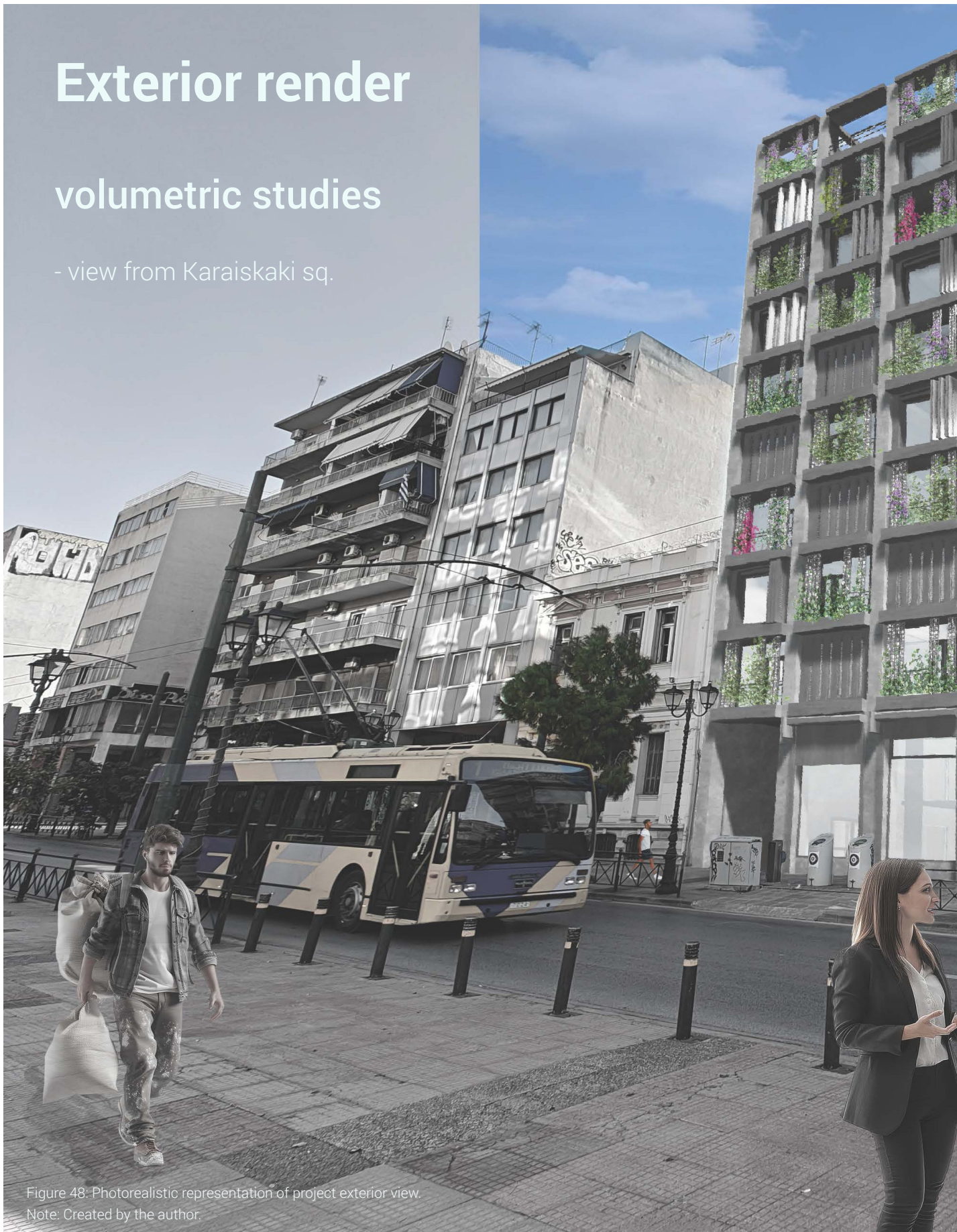


Figure 48: Photorealistic representation of project exterior view.
Note: Created by the author.



Concept

volumetric studies

- zoom out



Figure 49 - 50:
Prefabricated CLT modules/ Urban design concept –
50 Modular Timber Apartments.
Note: Reprinted from Philippe Ruault (n.d.) via Pinterest and ArchDaily.

The conceptual approach of this project is structured through two complementary perspectives: a “zoom-out” perspective and a “zoom-in” perspective.

At the macro scale, the zoom-out concept organizes the project development into three distinct phases:

Phase A: involves the documentation and configuration of the existing structural framework.

Phase B: encompasses the installation of prefabricated Cross-Laminated Timber (CLT) elements, with those vertical one to be deployed every two spaces.

Phase C: addresses the subsequent modification and/or addition of CLT modules, responding to evolving spatial, structural, or functional requirements.

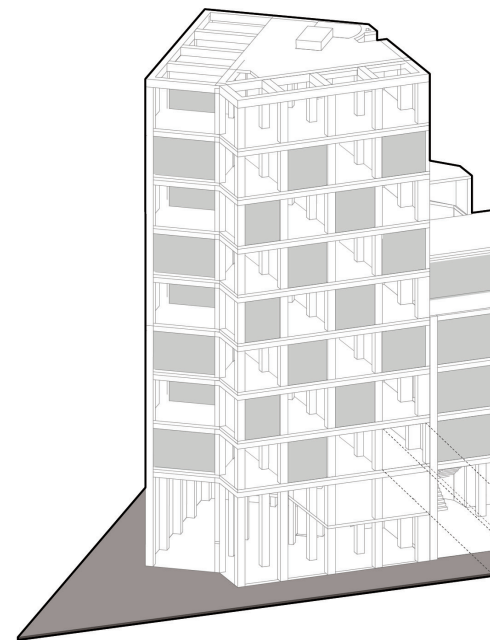
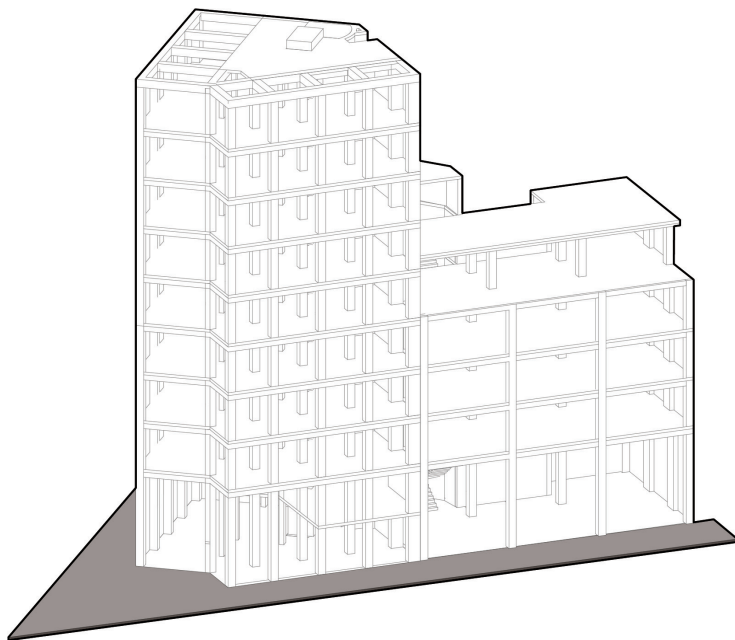


Figure 51: Concept analysis (zoom out)./ Note: Diagram created by the author.

phase A: existing structure configuration

phase B: CLT

In parallel, the zoom-in concept examines the construction process at the micro scale. Within this framework, the prefabricated CLT “boxes” are subdivided into three smaller components to facilitate transportation and handling.

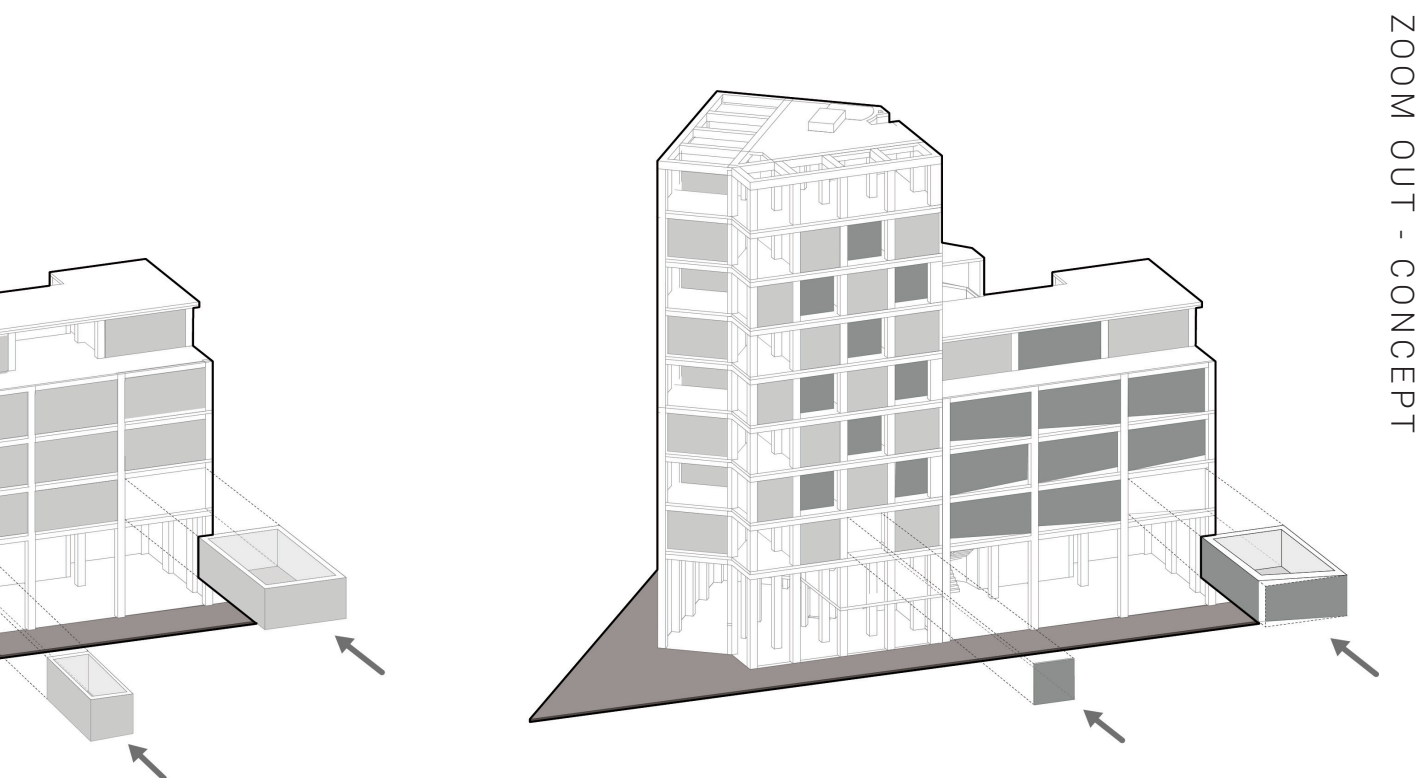
These components are then lifted into position using cranes and mounted onto the existing concrete structure.

A key feature of this installation process is the use of pre-installed rail systems integrated into the building. Once the modules are rolled into their designated positions along the rails, they are joined and connected to form cohesive living units.

The rails are designed to remain as permanent features within the structure, ensuring that the CLT boxes are securely anchored while maintaining a consistent offset of 100 millimeters from the existing concrete slab.

This intentional gap is reserved for the integration of mechanical, electrical, and plumbing (MEP) systems, thereby optimizing the building’s serviceability without compromising structural performance.

The final step in the construction sequence involves the installation of prefabricated CLT façade elements, completing the architectural structural and functional expression of the new intervention.

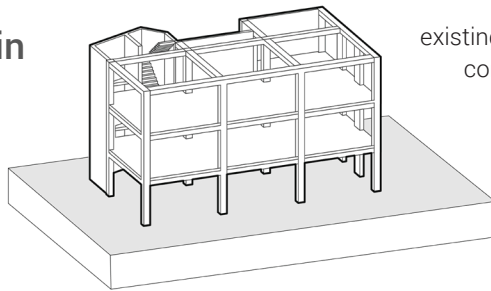


modules installation **phase C:** CLT modules modification/addition

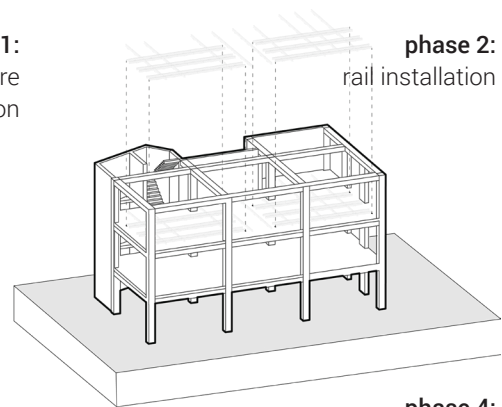
Concept

volumetric studies

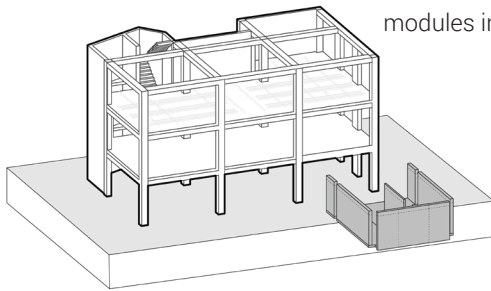
- zoom in



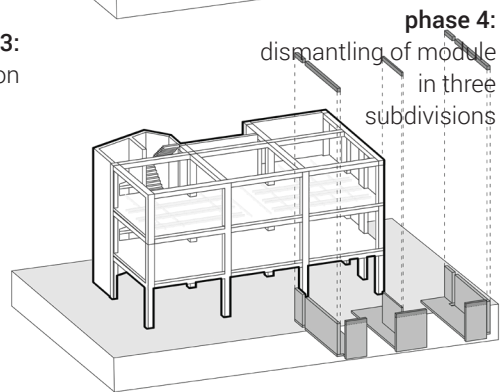
phase 1:
existing structure
configuration



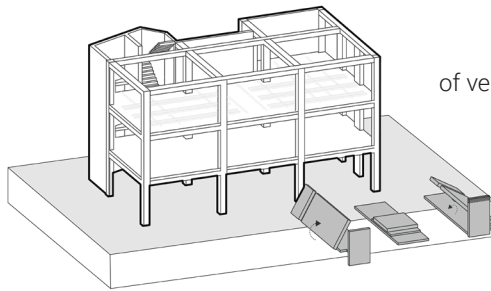
phase 2:
rail installation



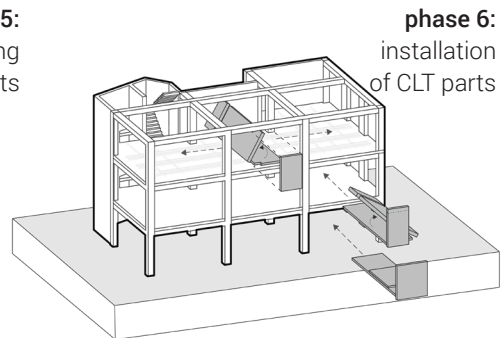
phase 3:
modules importation



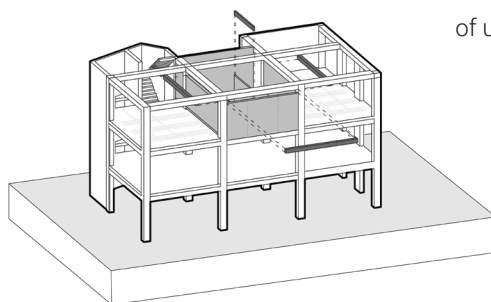
phase 4:
dismantling of module
in three
subdivisions



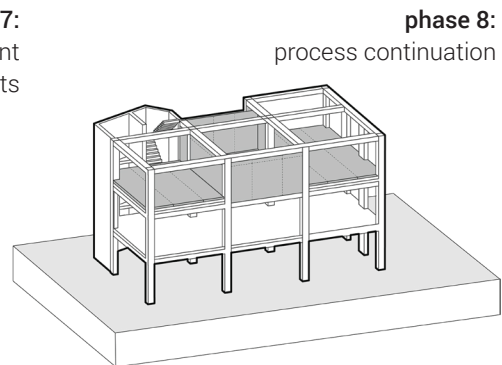
phase 5:
stacking
of vertical parts



phase 6:
installation
of CLT parts



phase 7:
placement
of upper parts



phase 8:
process continuation

ZOOM IN - CONCEPT

Figure 52: Concept analysis (zoom in)/ Note: Diagram created by the author.

Interview Insights

On April 9, 2025, as mentioned in the methods of research, an interview with Mr. Adam Kihlberg (Technical Business Development Manager at Södra Building Systems) was conducted via an online meeting.

The purpose of the interview was to gather professional insights regarding the structural, technical, and environmental aspects of integrating prefabricated CLT elements into an existing concrete framework.

Key findings from this discussion are summarized below and have influenced the development of the proposed concept and the design strategy. (The full interview transcription can be found in the appendix.)

Key intakes:

Structural: The existing concrete frame must be inspected for load capacity. CLT boxes in this occasion are not structural and must be anchored against movement.

Installation: Sliding boxes on rails is feasible, but tolerances must be carefully planned for.

Moisture: Use of membranes to protect the wood-concrete surfaces are useful for keeping the assembly area dry.

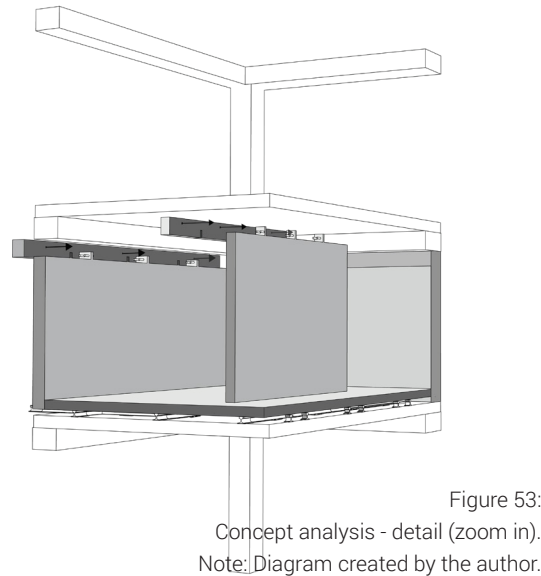
Fire Safety: Gaps between modules must be fireproof, with anticipation of more strict future regulations.

Connections: Minimal fastening required unless seismic specifications require more, with simple solutions such as screws or steel angles are adequate.

Prefabrication: Off-site manufacture saves time and money, making it a feasible option despite higher CLT costs.

Hybrid Construction: The combination of concrete and timber is a developing trend motivated by environmental concerns.

Resources: Rotho Blaas manuals and Swedish handbooks are helpful for connection detailing.



Facade design

The façade of the project draws direct inspiration from local architectural heritage, referencing some of the most iconic neoclassical buildings in Athens.

These historical structures are characterized by large wooden louvers or sliding shutters, slender balconies with ornate metal railings, and generously proportioned openings in both doors and windows.

Additionally, the use of expansive glazed storefronts at the ground level reflects the typical commercial use found in many such buildings, anchoring the design in its urban and cultural context.



Figure 54: Facade details (louvers) – local architecture.
Note: Adapted from Neoclassical architecture in Greece.
Original photo from Alamy (n.d.), edited by the author.

Example A:

- Wooden large wooden sliding shutters

Example B:

- Expansive glazed storefronts at the ground level

Example C:

- Narrow balconies with metal railings

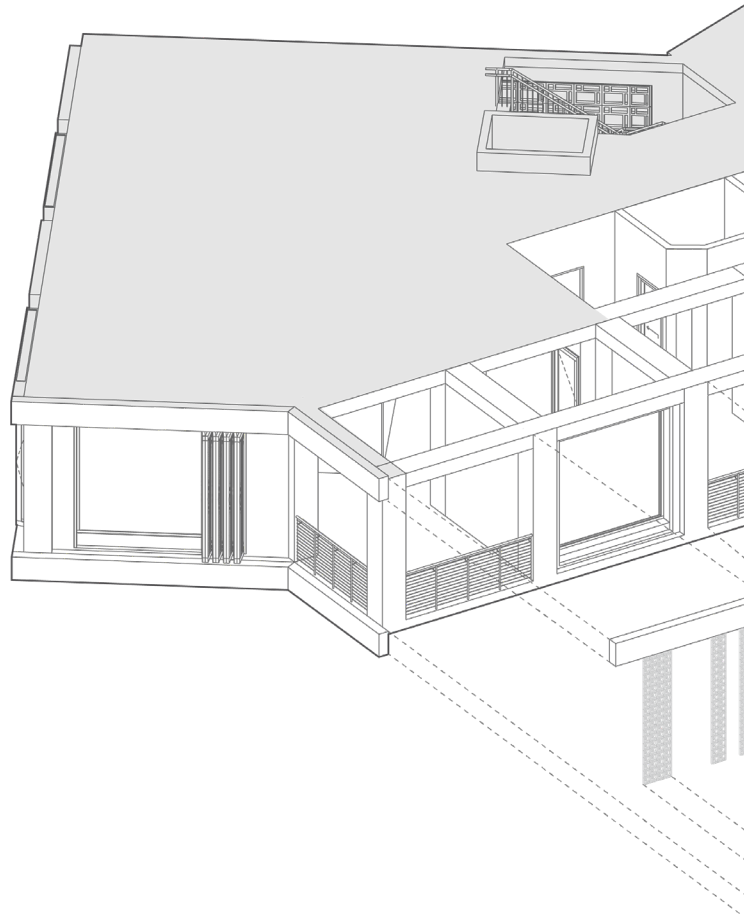




Figure 55: Facade details (entrances) – local architecture.
 Note: Adapted from Athens' Neoclassical Gems,
 Greece Is (n.d.), edited by the author.



Figure 56: Facade details (windows) – local architecture.
 Note: Adapted from Neoclassical buildings in Athens,
 Reddit (n.d.), edited by the author.

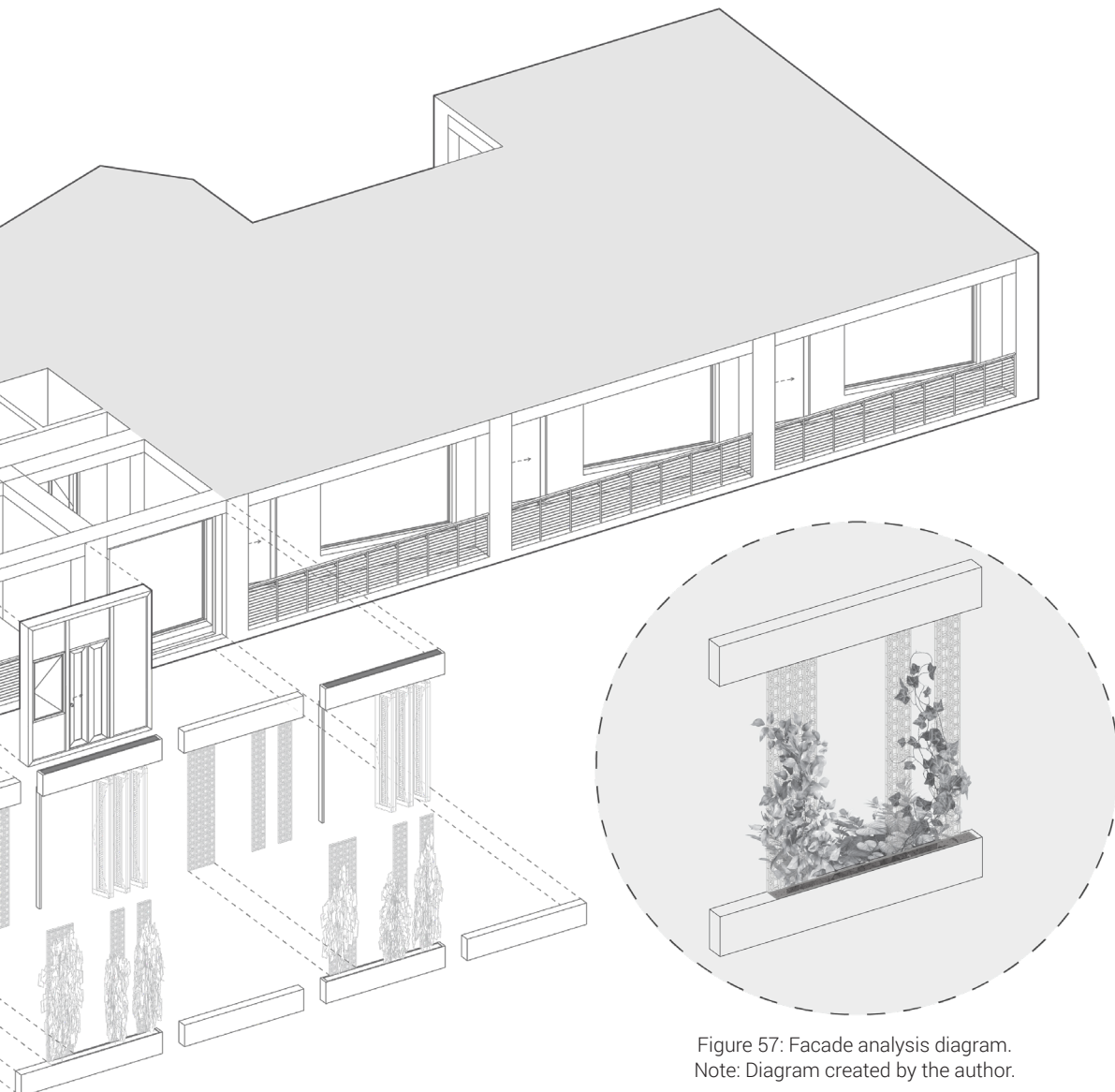


Figure 57: Facade analysis diagram.
 Note: Diagram created by the author.

Diagrams

Axo – Environmental studies

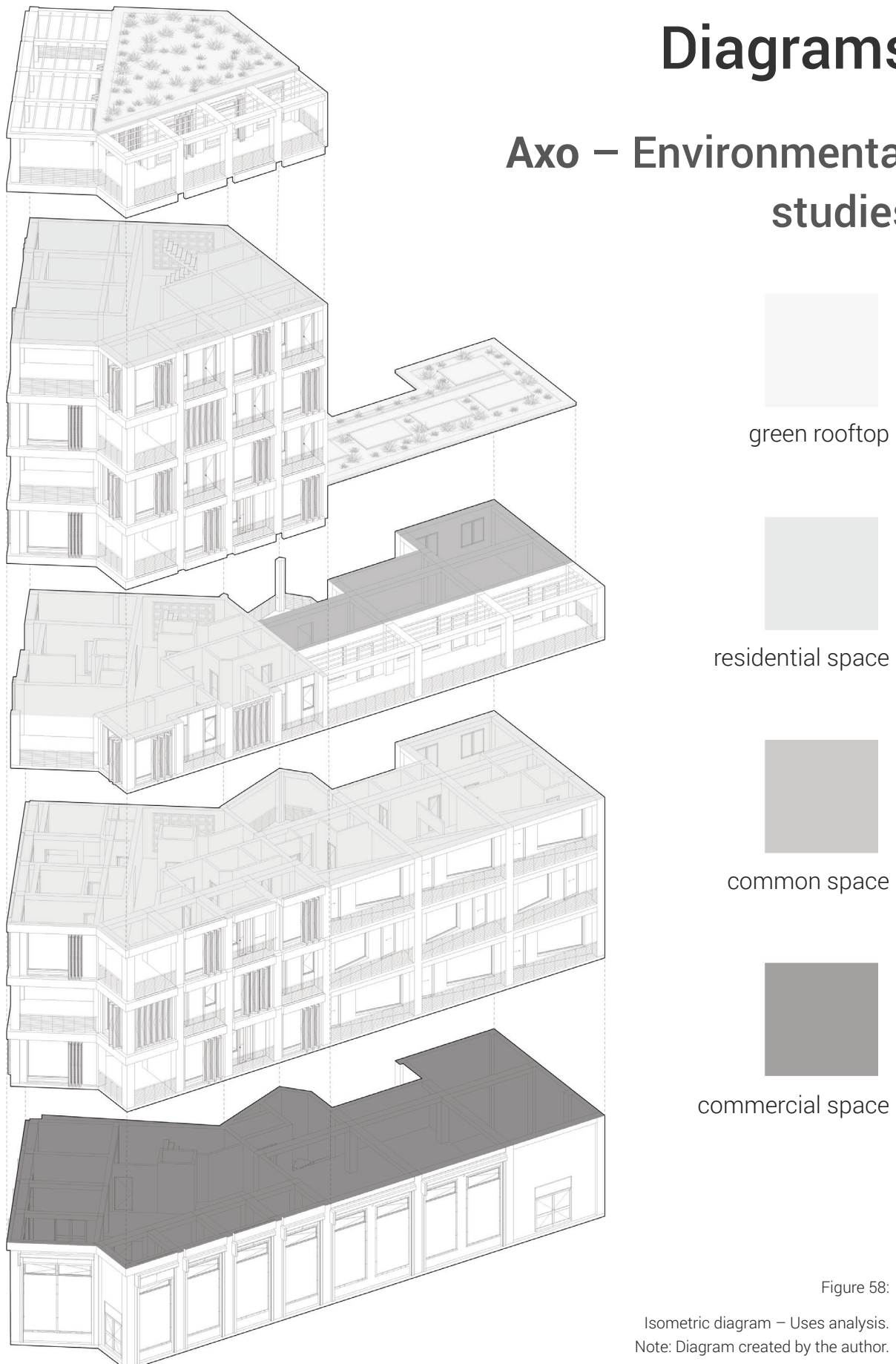
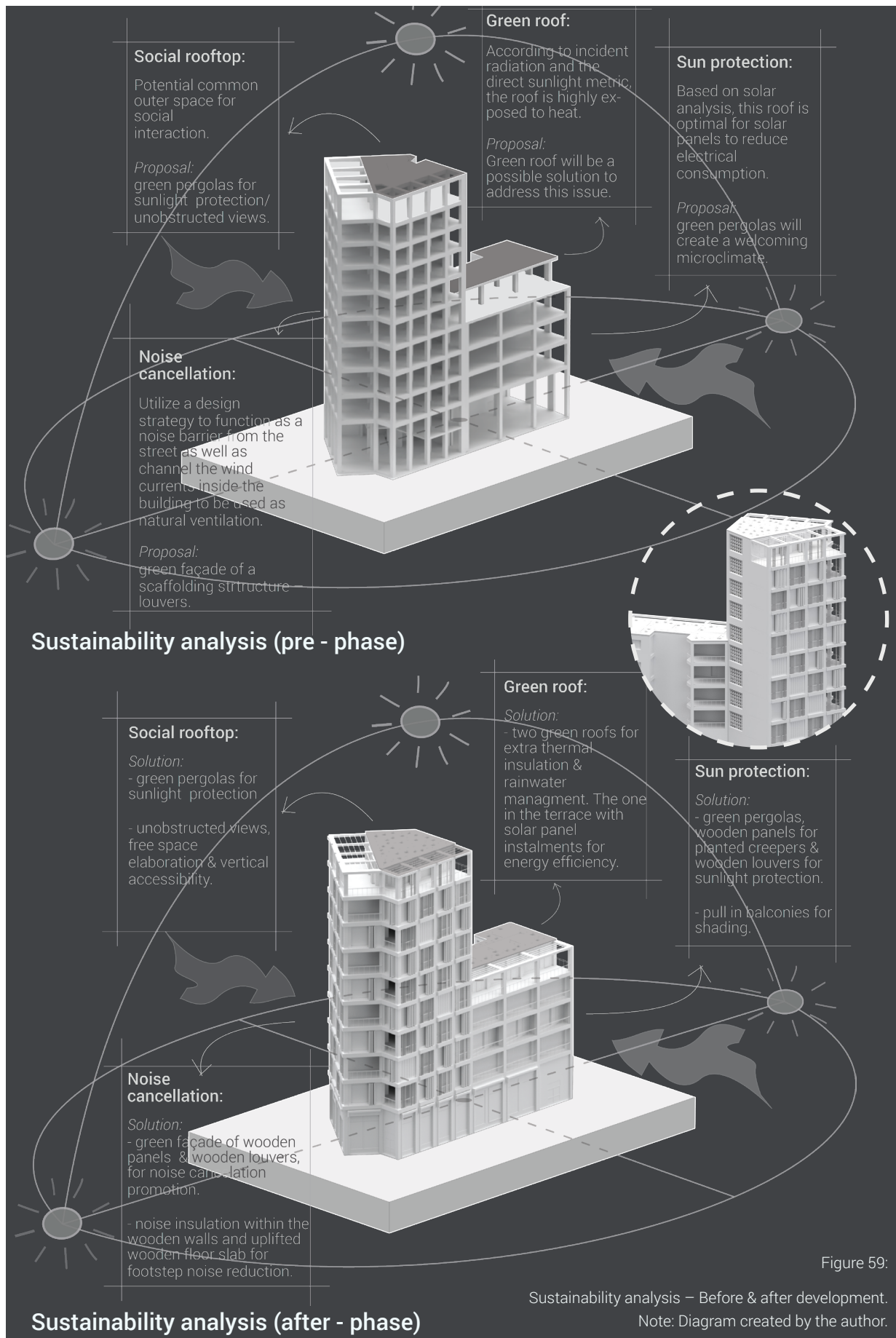


Figure 58:

Isometric diagram – Uses analysis.
Note: Diagram created by the author.



Structural Details

construction techniques

- detail section/ facade
- various details

According to theory, the drawings and diagrams below depict a potential structural solution for connecting CLT walls to existing RC buildings, providing reinforcement while allowing for movement through specifically engineered joints and connections.

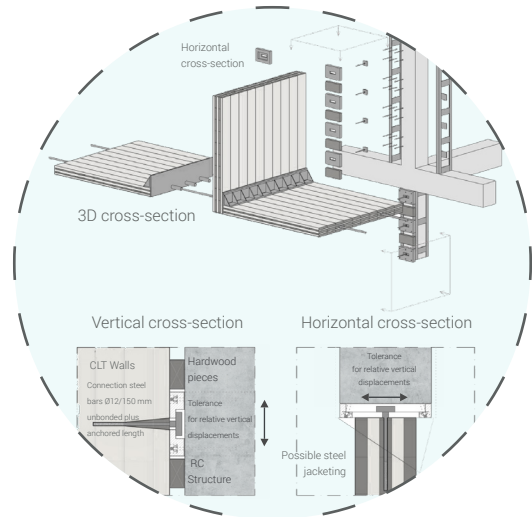


Figure 60:
Seismic strengthening concept using CLT walls.
Note: Adapted from Badini et al. (2022).

structural detail 3D
- connectivity



Figure 61: Facade detail (right side).
Note: Diagram created by the author.

General observations & assumptions

Rail and Wheel Rolling Installation

Stainless steel rails are anchored to the existent concrete slab with expansion bolts. CLT modules are mounted on small steel or polyurethane-coated wheels, which run smoothly along the rails. To guarantee correct movement during installation, the rail profile has guiding lips.

Rail and Wheel Rolling Installation

After rolling into place, modules are secured with heavy-duty adjustable steel brackets. Brackets, which are fastened to the steel rails and the underside of the module, might be L or U shaped. The brackets are fastened into the reinforced areas of the CLT slab using bolts or lag screws. In order to maintain a constant 100 mm service gap, the brackets must be able to be adjusted vertically.

Rail and Wheel Rolling Installation

MEP installations (heating, ventilation, and electrical) use the 100mm gap between the CLT module and the concrete slab as a service zone.

To maintain fire safety and aesthetics, this gap can be filled with detachable panels made of metal or CLT after services have been routed. To adhere to safety regulations, service penetrations should be surrounded with fireproof wraps.

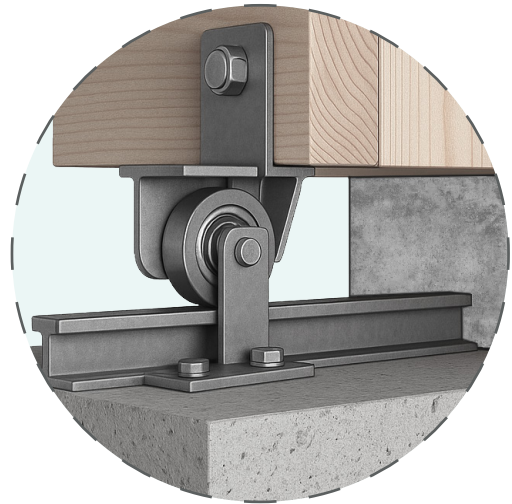


Figure 62:

CLT modules placement detail.

Note: Diagram generated with Canva AI, based on the author's description & edited by the author.

structural detail 3D - installation

Based on reasearch:

Considering the interior CLT components are not load-bearing, wall and slab thicknesses can be lowered to between 300 and 250 mm without sacrificing strength.

A lightweight, non-load-bearing CLT build-up of 150–200 mm is advised for slab assemblies.

To provide sufficient fire, moisture, and sound insulation, a common configuration consists of a 15 mm wood finish, 15 mm acoustic mat, 120–150 mm CLT core, 20 mm moisture barrier, and 20 mm fire-resistant mineral wool.

In order to maximize vertical space and improve the industrial style, it is suggested that the ceiling remain exposed concrete.

The composition of the internal wall consists of a 20 mm ventilated cavity, a 160 mm CLT panel, a 30 mm mineral wool fire insulation layer, a 15 mm fire protection or cavity layer, and an interior wood finish of 15 mm.

Further structural details are presented in the theoretical section.

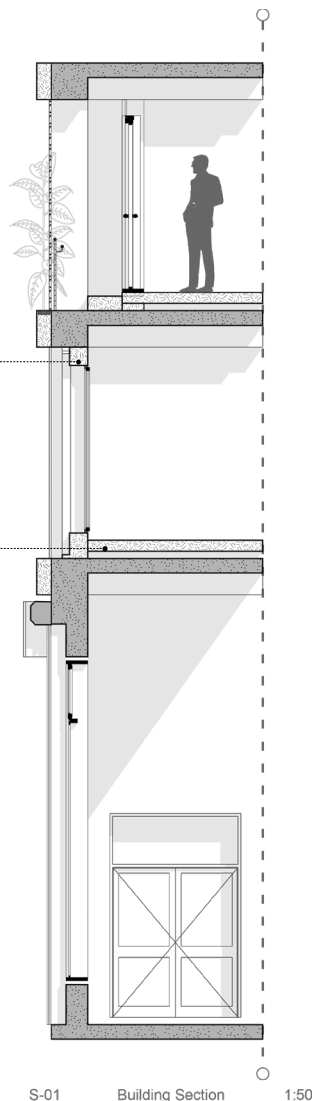


Figure 63: Facade detail (right side).

Note: Diagram created by the author.



2D plans

vertical sequence

- South elevation
- North elevation
- East elevation

- Section S 01



Figure 65:

South elevation – Extended plan (1:500).

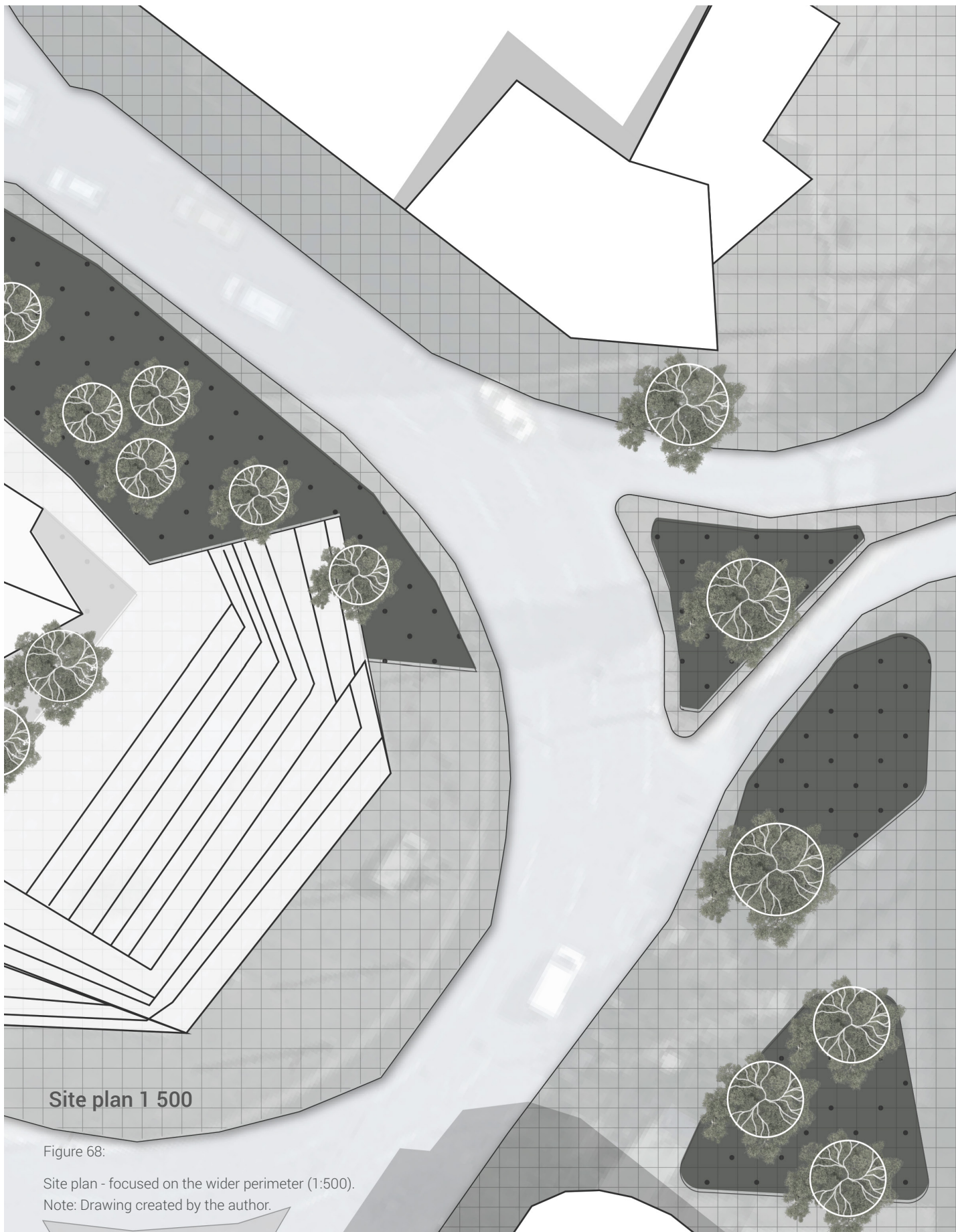
Note: Drawing created by the author.



Figure 66: East elevation (1:100).
Note: Drawing created by the author.



Figure 67: North elevation (1:100).
Note: Drawing created by the author.



Site plan 1 500

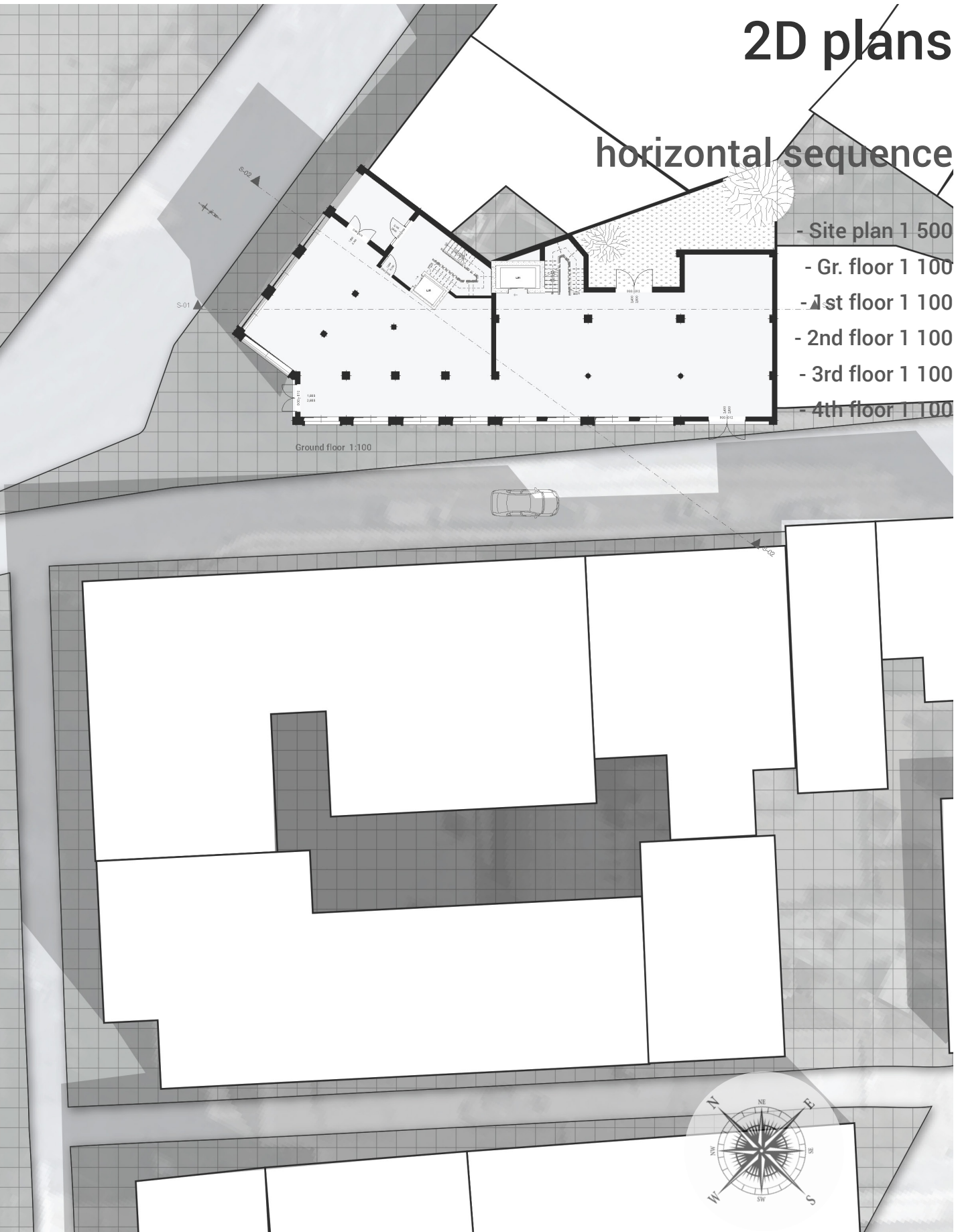
Figure 68:

Site plan - focused on the wider perimeter (1:500).

Note: Drawing created by the author.

2D plans

horizontal sequence



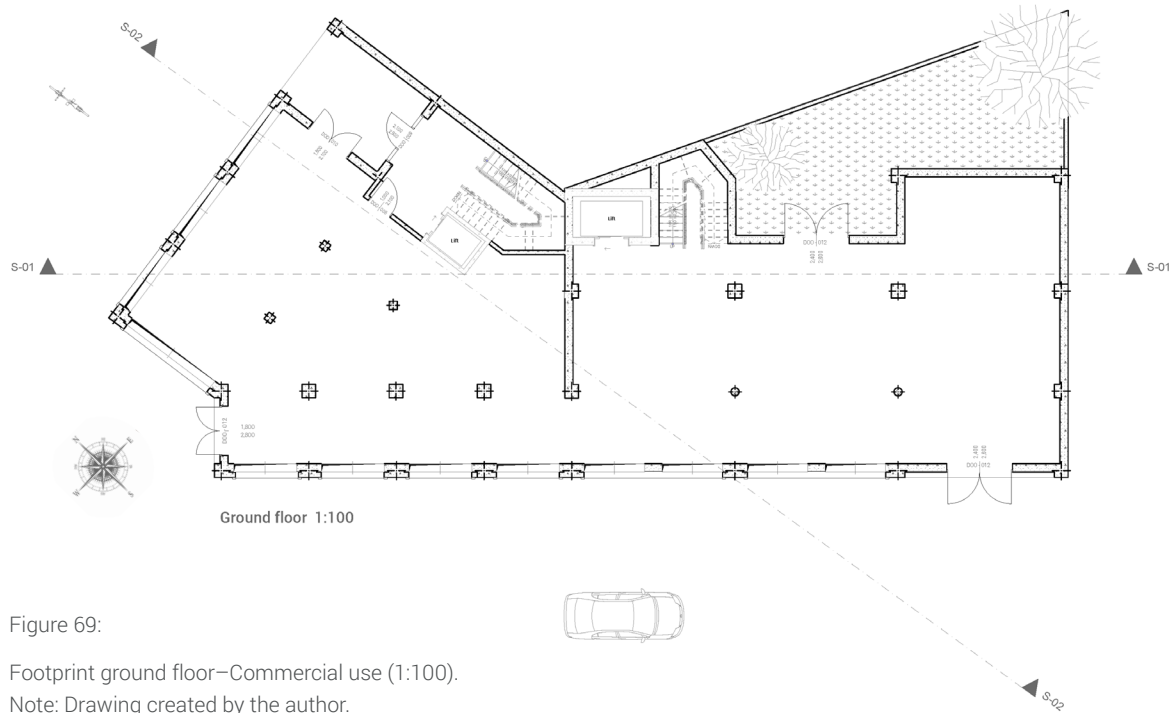


Figure 69:

Footprint ground floor—Commercial use (1:100).
Note: Drawing created by the author.

Footprint 1 100/ Ground floor

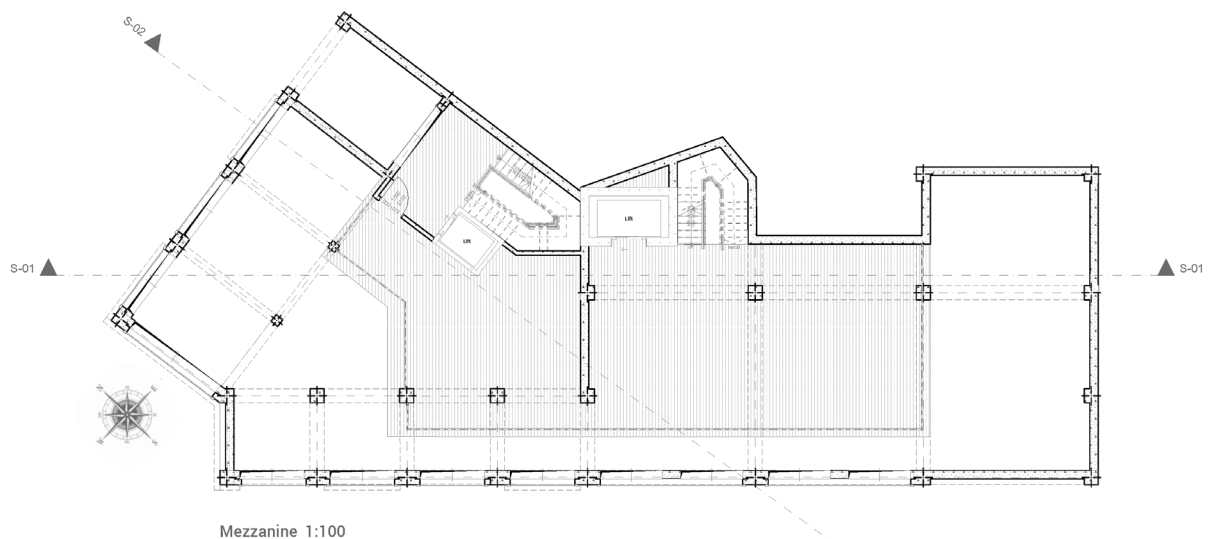


Figure 70:

Footprint mezzanine – Commercial use (1:100).
Note: Drawing created by the author.

Footprint 1 100/ Mezzanine

Notes associated with the layout - Design Across Borders

This project merges Swedish and Greek housing standards into a hybrid residential design tailored for Athens. Influenced by Sweden's welfare state principles like accessibility, livability, and sustainability, the final result correlate these values within the spatial and cultural conditions of Greek urban housing. In this concept accessibility is adopted through widened doorways and buffered private spaces such as wheelchair-accessible WC , while compact Greek layouts are implemented by designing multifunctional, yet comfortable, apartments with larger bedrooms. Concerning the lack of basement integrated storage and laundry, are included in all apartments.

Passive solar design, green roofs, and shading devices respond to the Mediterranean climate while cross-ventilation and natural daylight, are enhanced by following Sweden's strict requirements of livable spaces connected to natural light sources.

Shared balconies and rooftop spaces introduce Swedish ideas of communal living, fostering interaction in a context where private ownership typically dominates. The reuse of the existing concrete structure, combined with CLT modules, reflects a sustainable and adaptable construction strategy.

The design is focused on the 1st & 2nd floors (standard floor A& B), which are fully furnished to showcase all the ideas in practice. Upper floors are left unfurnished but mirror the same layouts as a showcase of the areas of residential floors. Circulation areas, terraces and common spaces are exhibited with less detail but with purpose of showing accessibility, vertical continuity, and potential for flexibility and future adaptation.

Overall, the floor plans serve as a spatial negotiation between two housing models, respecting Greek legal base while introducing Swedish standards for healthier, more inclusive urban living.

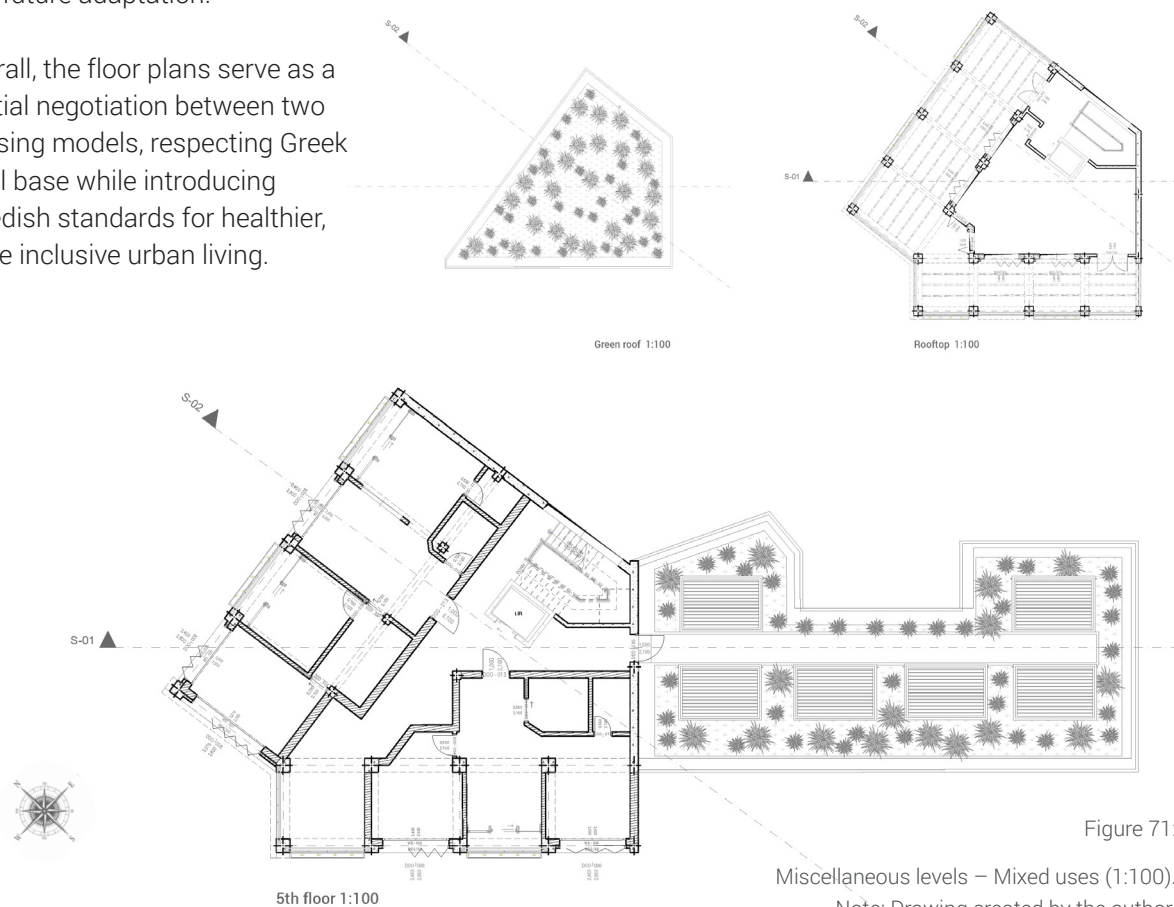


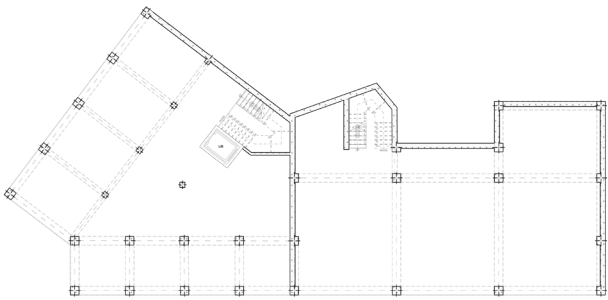
Figure 71:

Miscellaneous levels – Mixed uses (1:100).
Note: Drawing created by the author.

Footprint 1 100/ Rooftop - terrace

horizontal sequence A

comparison
of existing with
designed new development



Existing situation - standard floor



Figure 72: Footprint 1 100/ 1st floor - standard floor A
Footprint standard floor plan A – Residential use (1:100).
Note: Drawing created by the author.

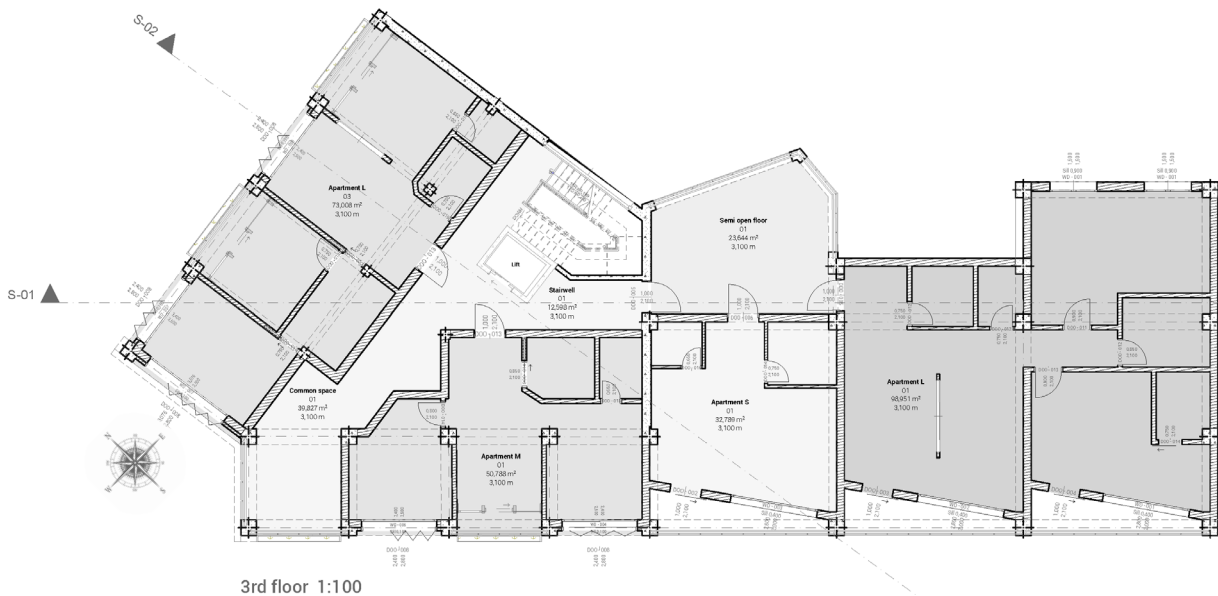
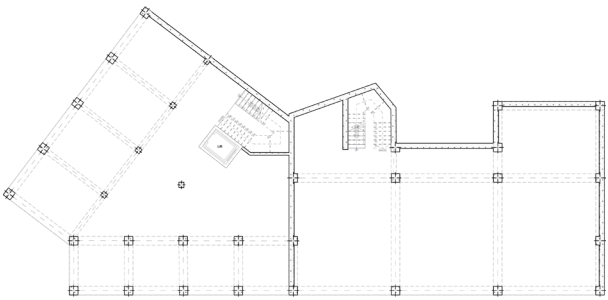


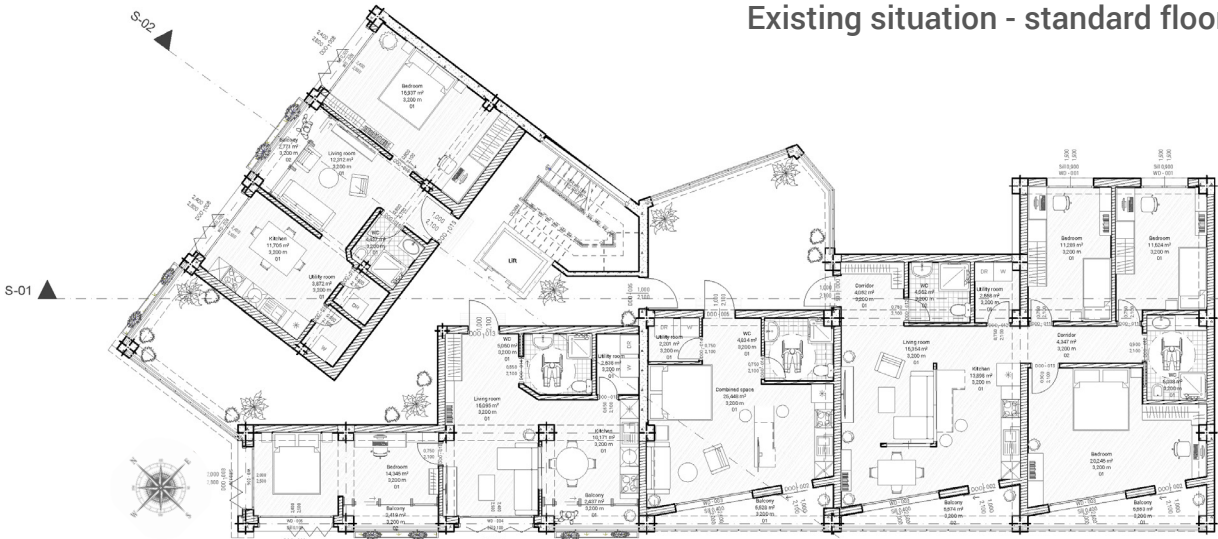
Figure 73: Footprint 1 100/ 3rd floor - standard floor A
Footprint standard floor plan A – Area metrics (1:100).
Note: Diagram created by the author.

horizontal sequence B

comparison
of existing with
designed new development



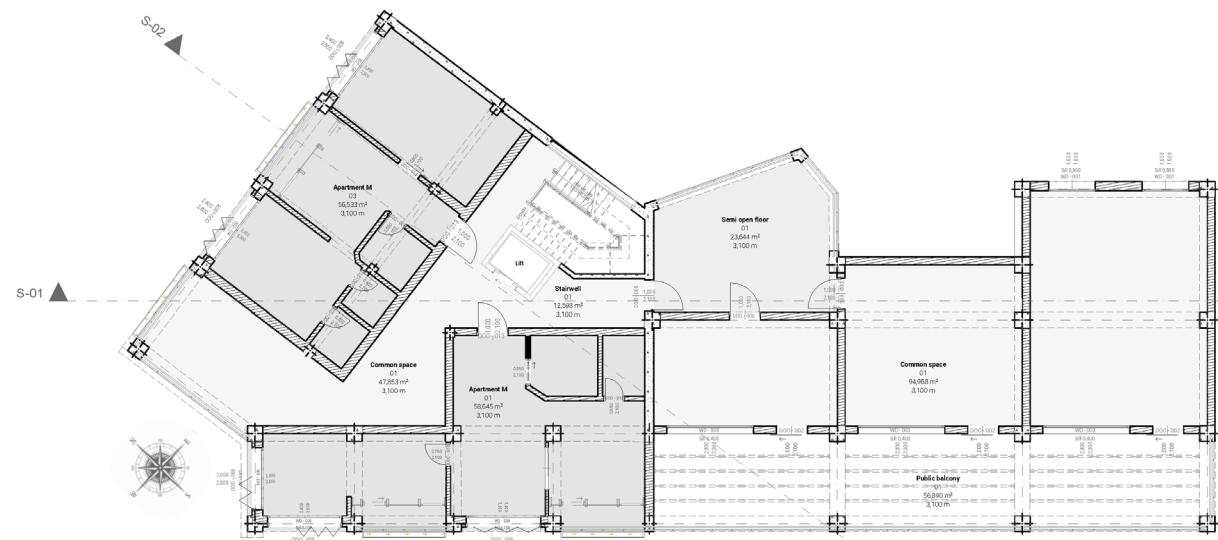
Existing situation - standard floor



2nd floor 1:100

Figure 74:
Footprint standard floor plan B – Residential use (1:100).
Note: Drawing created by the author.

Footprint 1 100/ 2nd floor - standard floor B



4th floor/terrace 1:100

Figure 75:
Footprint standard floor plan B – Area metrics (1:100).
Note: Diagram created by the author.

Footprint 1 100/ 4th floor - standard floor B

OVERVIEW TABLE

North Meets South: A synthesis of swedish & greek housing ideals

Aspect	Swedish Standards
Accessibility	Universal Design, wheelchair-ready
Apartment size	Generous, function-specific spaces
Energy efficiency	Very high (NZEB, passive house)
Climate adaptation	Cold climate – insulation, mechanical systems
Storage & Laundry	Integrated & generous
Construction materials	Sustainable (wood, CLT, non-toxic)
Shared amenities	Emphasized (laundry, bike rooms, saunas, common areas)
Design philosophy	Welfare-state, livability-focused
Doors (swing & placement)	Outward or sliding bathroom doors for safety, buffered from social areas, wide for accessibility
Daylight & Ventilation	Strict requirements on day-light access & cross-ventilation, windows in all habitable rooms are a must

Greek Standards	Design proposal
Limited, mostly in new public projects	Follow Swedish accessibility standards as much as possible
Compact, multifunctional rooms	Compact yet livable Flexible layouts with larger bedrooms
Moderate to low (but improving via KENAK)	Use passive techniques: solar roof, green roofs, vertical green facades
Hot climate – shading, natural ventilation	Shading, natural ventilation using pergolas, green shading, shading corners
Often improvised or minimal	Integrated storage, with separate laundry spaces where possible
Concrete frame, tile floors, basic finishes	Sustainable materials: wood, CLT, non-toxic finishes, reuse existing concrete
Minimal (mostly private use)	Shared balconies, common rooms, and gathering spaces for social interaction
Economical, ownership-based housing culture	Economical as possible, informed by welfare principles and community well-being
Inward-swinging doors, bathrooms often open to living areas standard widths, limited accessibility	Inward-swinging doors, buffered bathrooms, standard width widened when possible
Good daylight access via large openings and balconies, cross-ventilation often achieved naturally thanks to layout & climate	Follow Swedish daylight access norms, large openings, cross-ventilation, small balconies

Table 02: Comparative analysis of Greek & Swedish design strategies – Implementation.
Note: Table created by the author.

Interior renders

different perspectives

- inside the apartment
- the stairwell
- common balcony



Interior render/ Apartment inner space

Figure 76: Photorealistic representation of apartment interior space.
Note: Rendering created by the author.



Discussion - Reflexions - Assumptions

Interpretation of Findings

The findings of this thesis demonstrate that CLT, when combined with existing concrete frameworks, offers a viable solution for addressing the environmental and housing challenges in Athens. The research shows that CLT provides significant advantages in terms of carbon reduction, thermal performance, construction speed, spatial flexibility and aesthetics. These findings directly respond to the research questions by highlighting CLT's environmental superiority over concrete, its capacity for prefabricated and modular design, and its potential to enable adaptable, user-responsive housing. In essence, CLT emerges as a system that supports innovative housing typologies suited to the dynamic urban conditions of southern Europe. (Bhandari et al., 2023)

Reflexion of the case study

The case study explored the potential of inserting 3D dismantled modular units within an existing structural framework. While this approach offers promising advantages in terms of prefabrication and rapid assembly, it may not represent the most suitable solution in this particular context. The application of 2D wooden elements, such as CLT walls - floors - slabs etc, appears to be an equally practical and adaptable alternative, potentially addressing several technical challenges related to integration and tolerances. Given the complexity of such hybrid interventions, interdisciplinary collaboration across architectural, structural, and building physics disciplines is essential to resolve the range of issues that may arise during the implementation process. Furthermore, the study suggests that modular techniques tend to perform more effectively when applied to regular structural geometries. As evidenced by the more straightforward configuration in the second part of the building, irregular frameworks can introduce complications that limit the efficiency and feasibility of modular systems.

Contextualization

By proposing the reuse of underutilized frameworks through prefabricated CLT additions, the thesis responds directly to local environmental pressures, economic constraints, and the demand for affordable housing. Globally, this study aligns with broader EU strategies for sustainable urban development and carbon neutrality, demonstrating that CLT can be localized successfully even in countries lacking a native timber industry.

Implications

As for the academic Impact, the thesis advances architectural knowledge by exploring the integration of CLT into hybrid systems for adaptive reuse. It also bridges the gap between design theory and material technology, offering a holistic framework for sustainable housing development. On the other hand, as practical Impact, practitioners, policymakers, and developers can benefit from the proposed system as a guideline for integrating CLT in urban regeneration projects.

Last but not least the findings introduce design strategies, policy frameworks and potential certification pathways (LEED or else) for the under examination design strategy.(Simeon, Oladiran, Otufowora, & Gabriel, 2024)

Recommendations

Future research should involve collaboration with local municipalities or contractors to implement pilot projects and collect performance data. Regulatory bodies should consider developing national standards for timber construction and hybrid systems. From a design perspective, more in-depth exploration of user interaction with adaptable housing models in the Greek context is recommended.
(Simeon, Oladiran, Otufowora, & Gabriel, 2024)

Future Research Directions

Several avenues for further research have emerged. These may include:

- Post-occupancy evaluations of CLT housing units in similar climates to assess thermal comfort, acoustics, and social use.
- The development of a Greek CLT guideline manual, detailing structural integration methods, logistics, and design adaptations.
- Economic feasibility studies based on local supply chains or potential public-private partnerships to reduce import costs.
- Exploration of policy mechanisms for supporting sustainable retrofits using hybrid timber systems, including tax incentives or subsidies.

APPENDIX I & II

Model

References

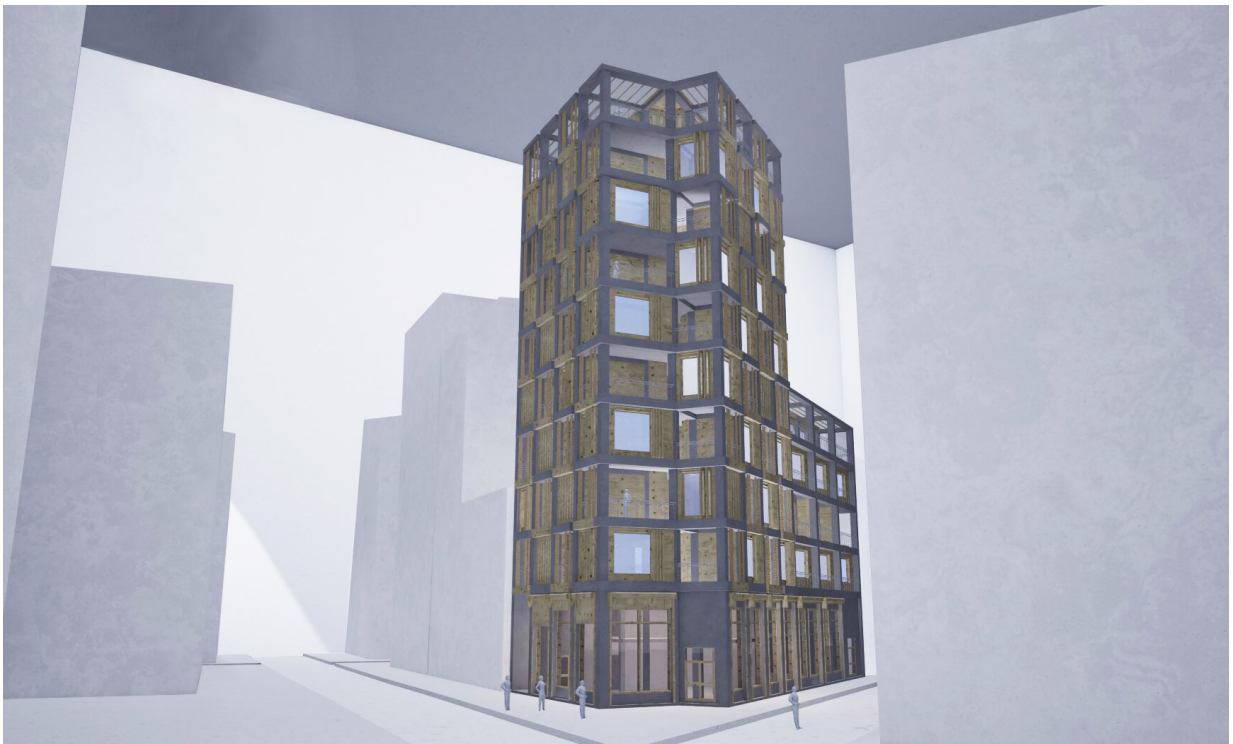
Interview transcript

Virtual model

Zoom out perspective



Zoom in perspective



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Figure list

Figure 01: Thesis process diagram. Created by the author.

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Interview transcription

Interview with Adam Kihlberg/

Technical Business Development Manager, Södra Building Systems

Date: April 9, 2025

Conducted by: Antonios Zormpas

Format: Online video call

Location: Remote (Athens – Väröbacka)

Transcript (Edited for clarity and readability)

Zormpas, A. (Interviewer): Adam, do you agree to start the recording and transcription of this meeting?

Kihlberg, A. (Interviewee): Yes, I accept.

Zormpas: Perfect. I'll start by sharing my screen. Can you see it?

Kihlberg: Yes.

Zormpas: Great. To introduce my project: the title is The Role of CLT in Modular Infill in Athens. The core idea is to insert prefabricated CLT modules into an existing concrete framework of an abandoned building in central Athens. The structure, as it currently stands, is just the concrete skeleton. My goal is to use CLT boxes as infill, forming apartments within the existing structure. The building has great connectivity and visibility due to its central location, and I've also run environmental simulations regarding sun exposure and wind. One key part of the design involves placing the boxes on installed rails within the slabs, leaving a 10 cm gap below for installation and flexibility.

Kihlberg: Interesting. Are there existing concrete floors, or is it just columns and beams?

Zormpas: The concrete floors are all in place.

Kihlberg: So, structurally they are load-bearing?

Zormpas: Yes, exactly. I plan to treat the existing structure as the main load-bearing system and place the CLT boxes within it. In that sense, CLT won't be used structurally, although I might incorporate some load-bearing walls for flexibility or demonstration.

Kihlberg: In similar hybrid projects I've seen, timber is often used structurally. If it's not structural here, you should still consider fire safety and tolerance issues. One major challenge is ensuring that the concrete structure can handle new loads. Moisture and tolerance between old and new materials are also important. Your idea to use a 10 cm raised floor for installation is clever, but tolerances and alignment will need careful planning.

Zormpas: Do you think sliding the boxes in on rails is feasible?

Kihlberg: We looked into a similar idea using IsoTimber and CLT with a rail system. It didn't proceed, but I think your idea is workable. Look at other industries—containers use rail or roller systems. You just need to ensure connections are secure to avoid movement post-installation.

Zormpas: What about moisture where CLT meets concrete?

Kihlberg: Always isolate with membrane or tape at any wood–concrete interface. Avoid trapping water. During construction, ensure water doesn't sit in joints. Ventilation during installation and detailing for moisture control are essential.

As for structural attachment, if the CLT isn't load-bearing, just stopping lateral movement might be enough. Use steel angles or screws for added restraint if needed. Earthquake requirements in Greece might change that, though.

Zormpas: What do you think about hybrid systems in general—especially in Sweden?

Kihlberg: There's still a divide between "Team Timber" and "Team Concrete" in Sweden, but we're seeing more hybrid solutions. We've recently started a project called EcoHybrid combining CLT and concrete slabs. Combining the best of both can address structural and environmental needs better than using one material alone.

Zormpas: From a financial perspective, do you think this system is viable?

Kihlberg: It depends. CLT is more expensive than stud walls, but prefabrication and time savings can offset that. If modules are made off-site and installed quickly, project timelines and costs can improve. Logistics and local conditions matter a lot.

Zormpas: I'll finish the details soon—can I send them to you for feedback?

Kihlberg: Absolutely. I'll also send you some helpful links, including supplier manuals like Rotho Blaas, which has great connection detailing.

Zormpas: That would be great. Thanks again for your time and insights—it was very helpful.

Kihlberg: My pleasure. Good luck with the project!

