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RESEARCH PLAN

TIMBER DURABILITY

AR3AW005 Architectural Wood Design Studio

ZOË EMMANOUILIDIS

5882990

Personal Information
Zoë Emmanouilidis
5882990

Studio
AR3AW005 Architectural Wood Design Studio
Gilbert Koskamp
Stijn Brancart
Max Salzberger

Title of Graduation Project
Sustainable timber use in architecture

2269 words

Content

Introduction

The building industry is increasingly focused on high-rise developments to accommodate urban population growth and maximize space efficiency. To create more housing or facilities within the existing urban landscape, the concept of "optopping" is used. This approach involves adding additional floors to relatively low-rise, existing buildings, effectively increasing urban density without expanding the city’s footprint. By building upward rather than outward, cities can make more efficient use of limited space and infrastructure, meeting growing demands for housing and services while preserving open land.

Problem statement

Contemporary high-rise and optopping architecture are heavily reliant on materials such as steel and glass, which are favoured for their structural strength, low maintenance requirements, and compatibility with modern design aesthetics. Despite the widespread use of steel and glass in high-rise buildings, their production is resource-intensive, significantly contributing to carbon emissions and energy consumption, which often contradicts sustainable building goals. This reliance on synthetic materials poses a challenge for the building industry, particularly in light of the urgent need for environmentally sustainable solutions.

Instead of relying on synthetic materials such as glass and steel, the building industry can utilize biobased materials that are more environmentally sustainable. Biobased materials, derived from renewable resources like plants and trees, offer numerous advantages over traditional synthetic options. Timber is a renewable, low-carbon material with a much smaller environmental footprint. Harvested sustainably, timber can act as a carbon sink, storing CO_2 over its lifetime, and it can be sourced responsibly without depleting resources. Despite these environmental benefits, timber remains underutilized in high-rise construction, particularly in exterior applications. The main barriers to its adoption include its natural susceptibility to decay, degradation, and general wear, which necessitate more intensive maintenance compared to steel and glass. Timbers’s vulnerability to environmental factors raises concerns over its durability in exterior, high-rise applications, where longevity, weather resistance, and structural integrity are critical. Nowadays, there is much more construction with timber, but this is often only evident in buildings that are relatively low, typically having 4 or 5 stories. It is often observed that beyond a certain height, timber is no longer used as a cladding.

The reluctance to incorporate timber in the exterior components of high-rise buildings reflects a gap in the industry's ability to treat and engineer timber for prolonged exposure to harsh outdoor conditions. Advances in timber treatment and preservation technologies, such as cross-laminated timber (CLT), modified timber, and specialized coatings, have shown promise in enhancing timber's durability, strength, and resistance to environmental stressors. However, these technologies are not yet widely adopted or optimized specifically for exterior use in high-rise construction, leaving an opportunity to further explore, develop, and promote sustainable timber-based solutions for these demanding outdoor applications.

This research will focus specifically on how timber can be engineered and treated for use in exterior elements, rather than interior structural applications. The aim is to develop approaches that improve timber's durability and reduce maintenance needs while maintaining its sustainability and aesthetic appeal for outdoor use.

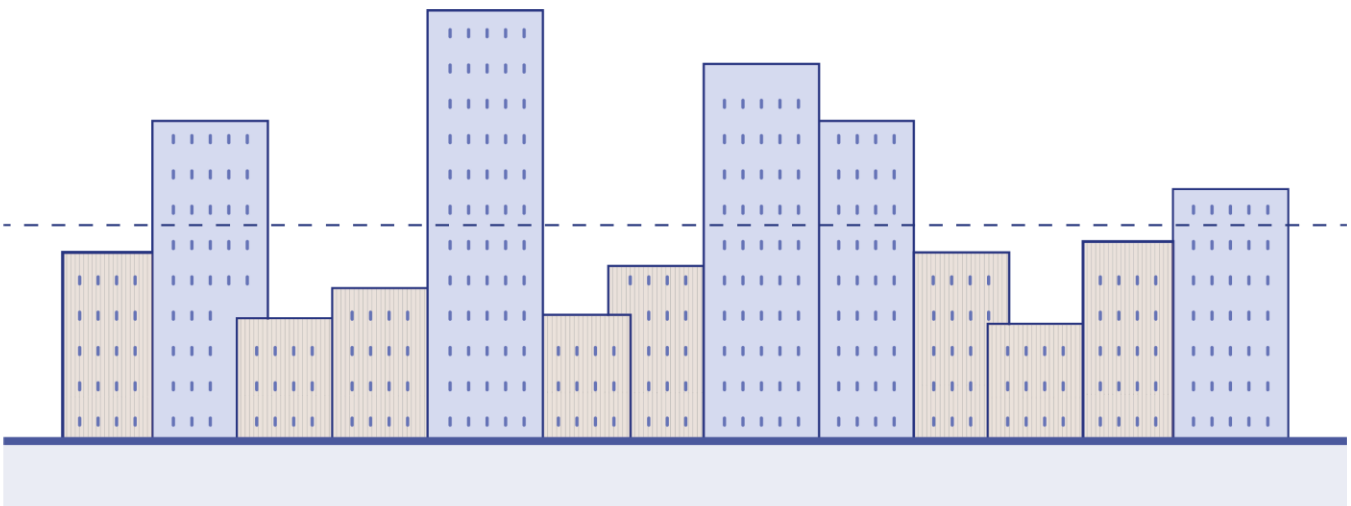

Figure 1 | Problem statement diagram | self-made

Overall Objective

Timber is often perceived as a material that lacks longevity and requires extensive maintenance. Consequently, materials like glass and steel are frequently favoured in high rise buildings and "optopping." Wile it is true that timber demands more attention than these synthetic alternatives, there are numerous methods available to enhance its sustainability and extend the lifespan of timber facades.

To address this issue, I aim to explore various techniques for making timber more durable, particularly in exterior applications, ensuring that it lasts longer when it is used in outdoor applications. It is important to note that the goal is not to create buildings that stand indefinitely. In today's building industry, many buildings are designed and built only to be demolished or repurposed after a relatively brief period. This transient nature of modern architecture reflects changing urban needs and demographic shifts, where buildings often serve specific purposes before becoming outdated. As Architects, we face the challenge of designing spaces that can adapt to future demands, and the longevity of a building is often uncertain.

For the design objective, I could focus on designing modular units that can be added to existing structures. These modular components can provide additional housing or facilities while minimizing the impact on the urban landscape. When these units are no longer required at their current location, they can be relocated and repurposed somewhere else. This approach not only addresses the immediate housing needs of urban populations but also embrace the principles of flexibility and adaptability in design.

Thematic Research Questions

From the problem statemen, the following research question has formed:

How can specific design and technical factors extend the lifespan of timber in exterior applications while maintaining environmental sustainability?

To answer this question, several sub-questions have been formulated:

1. *Which types of timber are naturally suited for outdoor durability and require minimal treatment?*

   This question aims to identify timber species that have natural qualities making them suitable for outdoor use without extensive treatment. I aim to invest the natural durability of different timber species. This research focuses only on timber species that are native to Europe, as timber sourced from regions like Asia is often less sustainable due to the environmental impact of long-distance transportation and concerns over deforestation practices. By solely selecting European timber species, the research aims to promote locally available, renewable resources that align better with sustainability goals. Using regional timber reduces the carbon footprint and also supports responsible forestry practices in Europe.

   The inherent durability of untreated timber will be examined, using established durability classes that range from 1 to 5. These classes provide a standardized way to assess how well different timber types withstand outdoor conditions, guiding the selection of species that require minimal intervention for extended durability. The scheme of the durability classes is shown in figure 2. This scheme will be used to answer the first sub question.

Durability class	**Designation**	**Timber life**
1	Very durable	25+ years
2	Durable	15-25 years
3	Moderately durable	10-15 years
4	Slightly durable	5-10 years
5	Not durable	0-5 years

Figure 2 | Information from Oldenburger et al. (2009)

2. *What non-chemical treatments effectively enhance timber's resistance to outdoor elements?*

   This question explores alternative methods for improving the durability of timber without resorting to chemical preservatives. Treatments without the use of chemicals may include thermal modification, which alters the timber's structure to improve its resistance to moisture and pests, or the application of natural oils and waxes that enhance water repellence and surface durability. By investigating these treatments, sustainable practices can be identified which protect timber from environmental factors such as moisture, UV radiation, and temperature fluctuations.

3. *Which design strategies can best protect exterior timber from environmental degradation?*

   The third question focuses on how design choices can protect timber from environmental damage. An effective design strategy might include using overhangs to provide shade and can be used as a shield for timber from the rain. Next to that, raising timber installations to avoid direct contact with moisture, and adding ventilation to reduce humidity can be design strategies to increase the durability of timber. By studying these design methods, the research can offer insights into how careful architectural design choices can increase the lifespan of timber in (high-rise) buildings.

   The environment in which timber is used greatly affects its exposure to wear and potential damage from fungi and insects. These conditions are categorized into five classes, known as "hazard classes." Each use class defines specific environmental factors that impact the timber's durability, helping to determine the level of protection or treatment needed for timber in various applications. The "hazard classes" are shown in a scheme in figure 3. This scheme will be used to answer the third sub question. Since this research focuses primarily on the exterior applications of wood on buildings, hazard classes 2 and 3 will be the most relevant.

Hazard class	Exposure and environment	Examples
1	For indoor use, above ground in a fully protected and well-ventilated area	Indoors, floor beams, purlins
2	For indoor use, above ground in an area that is protected from leaching and wetting	Pitched roofs, warm flat roofs, timber frame construction
3	For outside use, above ground. Periodic moderate wetting and leaching	Facade joinery, cold flat roof
4	Outside use. In ground. Contact with, or in fresh water. Extreme wetting, leaching and critical use	(Fence) posts, play structures, embankments, sheet piling
5	Marine use. Timber is permanently in contact with salt water.	Harbor works, piers, breakwaters, coastal defence

Figure 3 | Information from Oldenburger et al. (2009)

Thematic Research Methodology

To answer the primary research question; "*How can specific design and technical factors extend the lifespan of timber in exterior applications while maintaining environmental sustainability?"* a structured methodology will be used.

1. **Literature review**

   A literature review will be made to establish a theoretical foundation for the research by gathering existing knowledge on timber durability and sustainability. Technical information about the natural durability of different types of European timber species will be gathered. Next tot that, non-chemical preservation methods and effective design strategies for protecting timber will be researched and gathered.

   Expected outcome: This review will provide insights into the properties of different timber species and the existing methods for enhancing timber durability.

2. **Case studies**

   Various case studies will be examined to analyse applications of timber in exterior settings. Various projects will be examined that have utilized timber applications in exterior settings. Each project will be analysed to uncover the design choices made by architects to enhance the sustainability of the wood. Additionally, the study will consider projects that have faced challenges, such as wood deterioration, to identify the causes behind these issues.

   To gain deeper insights, architects will be interviewed to determine whether they considered sustainability in their approach to timber use. If they did, the interviews will explore how they addressed this aspect and what challenges they encountered during the design process. This combination of project analysis and interviews aims to provide a comprehensive understanding of both successful strategies and potential pitfalls in the sustainable use of timber.

   Expected outcome: A set of practical design principles and lessons learned from existing projects, offering insights into successful strategies for using timber.

3. **Interviews**

   Interviews will be held with architects, contractors and material experts who have experience in building with timber. Questions will focus on their approaches to working with timber and how they strive to enhance its sustainability in their projects. The initial step in this process is to identify individuals who are actively engaged in timber sustainability practices.

   As mentioned above, during the case study analysis, inquiries will also be made about specific projects and how the architect or contractor addressed the sustainability of timber in their works. This combination of interviews and case study evaluations will provide valuable insights into current practices and strategies for improving the durability and environmental performance of timber buildings.

Expected outcome: qualitative data that complements the findings from the literature review and case studies, highlighting practical challenges and innovative solutions in timber use.

4. Research by design

This method will be used to explore design interventions that can effectively extend the lifespan of timber in exterior applications. Conceptual design proposals will be developed that incorporate the insights gained from the literature review, case studies and interviews. Design prototypes or models will be created that illustrate various strategies for enhancing timber durability, such as innovative cladding systems, integrated ventilation, and protective overhangs.

Expected outcome: A collection of design prototypes or guidelines that demonstrate how specific design and technical choices can enhance the longevity and performance of timber in outdoor applications, serving as a resource for architects and builders.

Theoretical framework

To determine if the planned research is valuable and fills a research gap, a preliminary review of existing literature on this topic was conducted. Articles were searched using keywords such as *timber durability, wood classing, high-rise timber, natural timber durability, optopping, biobased materials, timber weathering,* and *timber treatments.*

This initial search yielded several articles that can serve as useful resources for the research.

1. "Het juiste hout op de juiste plaats" (2009) by Oldenburger et al. provides an overview of various timber types, their natural durability, and optimal applications. This article categorizes wood based on weather resistance, rot, and insect resistance, offering guidelines for selection appropriate timber for specific environments. This article is valuable for the research as it offers guidelines on timber types suitable for outdoor applications without chemical treatments.

2. *"Measuring-up in Timber"* (2014) Fleming et al. (2014) reviews the benefits and challenges of using timber in mid- and high-rise buildings. This article is valuable as it explores the technical and regulatory issues in high-rise timber design, offering insights into enhancing timber's durability and sustainability.

3. *"HOUTWIJZER: Gevelbekleding van Massief Hout"* (2024) by Centrum Hout detail types of wood, durability, and design practices for using solid wood in exterior cladding, with a focus on moisture and UV protection. This guide is relevant as it offers practical methods to enhance durability in exterior applications, supporting the study's goal of sustainable timber use.

4. *Building with Bio-Based Materials: Best Practice and Performance Specification"* (2017) written by Živković et al. discusses the use of bio-based materials in the building industry, focusing on wood and its environmental benefits, durability, and application suitability. It highlights best practices and design considerations to enhance sustainability and performance. This article is relevant as it provides insights into maximizing the durability of timber.

These are a few examples of useful sources; the following sources are also relevant to the research:

- Brun, G. (2023). When wood cladding degenerates. *FormAkademisk - Forskningstidsskrift For Design Og Designdidaktikk*

- Englund, F., SP Sveriges Tekniska Forskningsinstitut, & SP Trätek. (2010). Durability by design of wooden cladding and decking – an overview of guidelines and information sources.

- Liang, S., Gu, H., Bergman, R., & Kelley, S. S. (2020). Comparative life-cycle assessment of a mass timber building and concrete alternative.

- Özçifçi, A., & Okçu, O. (2007). The influence of the impregnating chemicals on the bonding strength of impregnated wood materials.

- Silva, A., & Prieto, A. (2021). Modelling the service life of timber claddings using the factor method.

- Unknown. (2021). *HOUT ZONDER CHEMISCHE VERDUURZAMING* [Technical Report].

As the research progresses, additional sources will be consulted that are not currently included in the research plan.

Relevance and expected results

The goal of this research is to create a matrix that helps architects and contractors select suitable timber species for exterior applications on buildings. The layout of the matrix is shown in figure 4.

Socially, the research encourages the use of timber, which is a renewable resource, over synthetic materials like steel and glass. By providing guidance on optimal timber species for outdoor conditions, the matrix aims to enhance the durability and longevity of wooden buildings without the use of chemical preservative treatments.

Scientifically, the research addresses gaps in existing literature about the performance of timber species in outdoor environments. By examining exposure and orientation, it deepens the understanding of timber behaviour on buildings.

The expected outcome is a practical matrix detailing the best timber choices for various conditions, benefiting architects, contractors, and builders by informing material selection and improving building performance. Additionally, the findings will support sustainability advocates and policymakers in promoting environment friendly construction practise, ultimately advancing the use of timber in sustainable architecture.

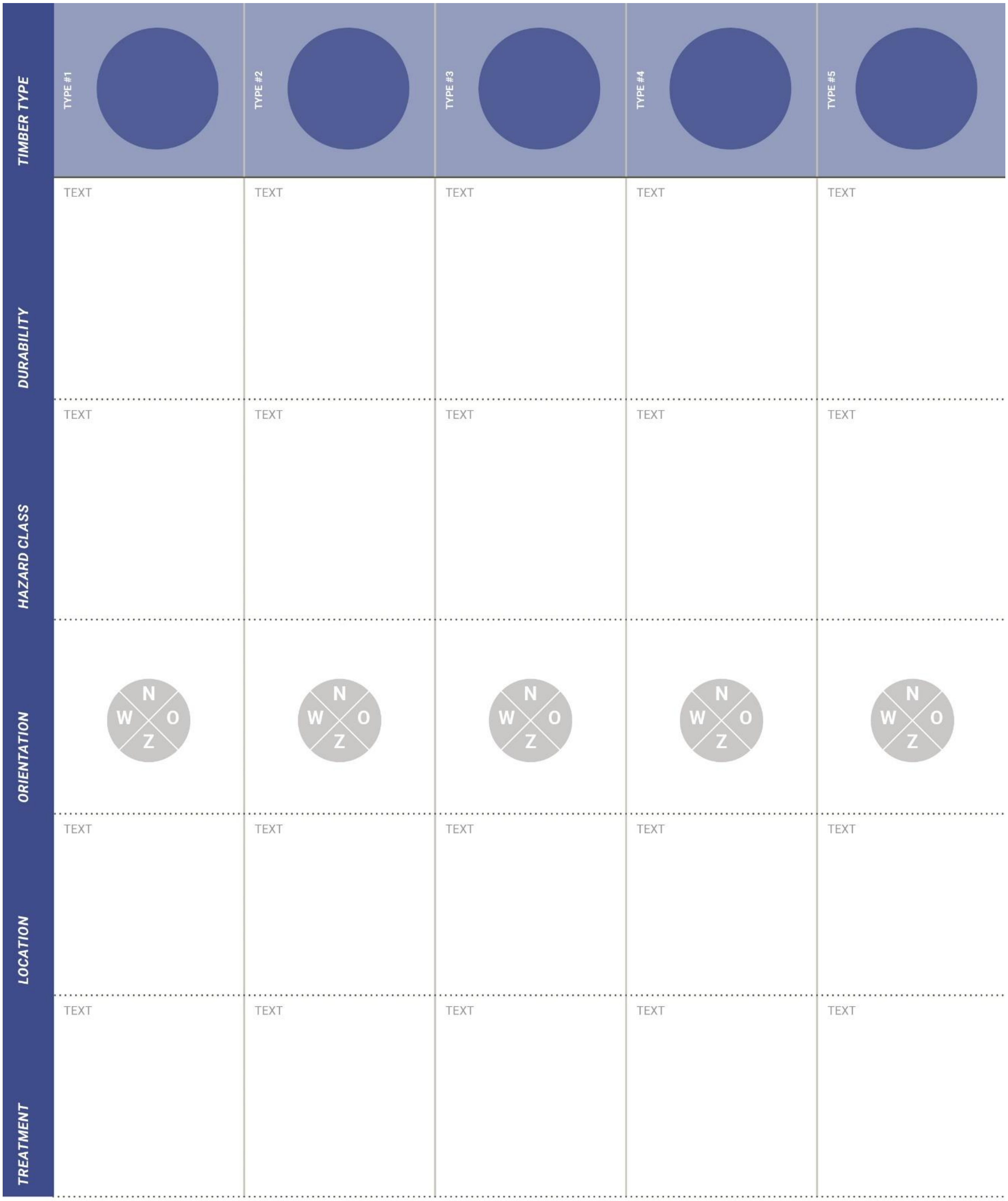

Figure 4 | Lay-out matrix | Self-made

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- Fleming, P., Smith, S., & Ramage, M. (2014). Measuring-up in timber: a critical perspective on mid- and high-rise timber building design. *Architectural Research Quarterly*, *18*(1), 20–30. https://doi.org/10.1017/s1359135514000268

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- Liang, S., Gu, H., Bergman, R., & Kelley, S. S. (2020). Comparative life-cycle assessment of a mass timber building and concrete alternative. *Wood And Fiber Science*, *52*(2), 217–229. https://doi.org/10.22382/wfs-2020-019

- Oldenburger, J., Van Den Briel, J., Stichting Probos, Stichting Hout Research, & Centrum Hout. (2009). *Het juiste hout op de juiste plaats*. https://www.probos.nl/images/pdf/rapporten/Rap2009_Het_juiste_hout_op_de_juiste_plaats.pdf

- Özçifçi, A., & Okçu, O. (2007). The influence of the impregnating chemicals on the bonding strength of impregnated wood materials. *Journal Of Applied Polymer Science*, *107*(5), 2871–2876. https://doi.org/10.1002/app.27370

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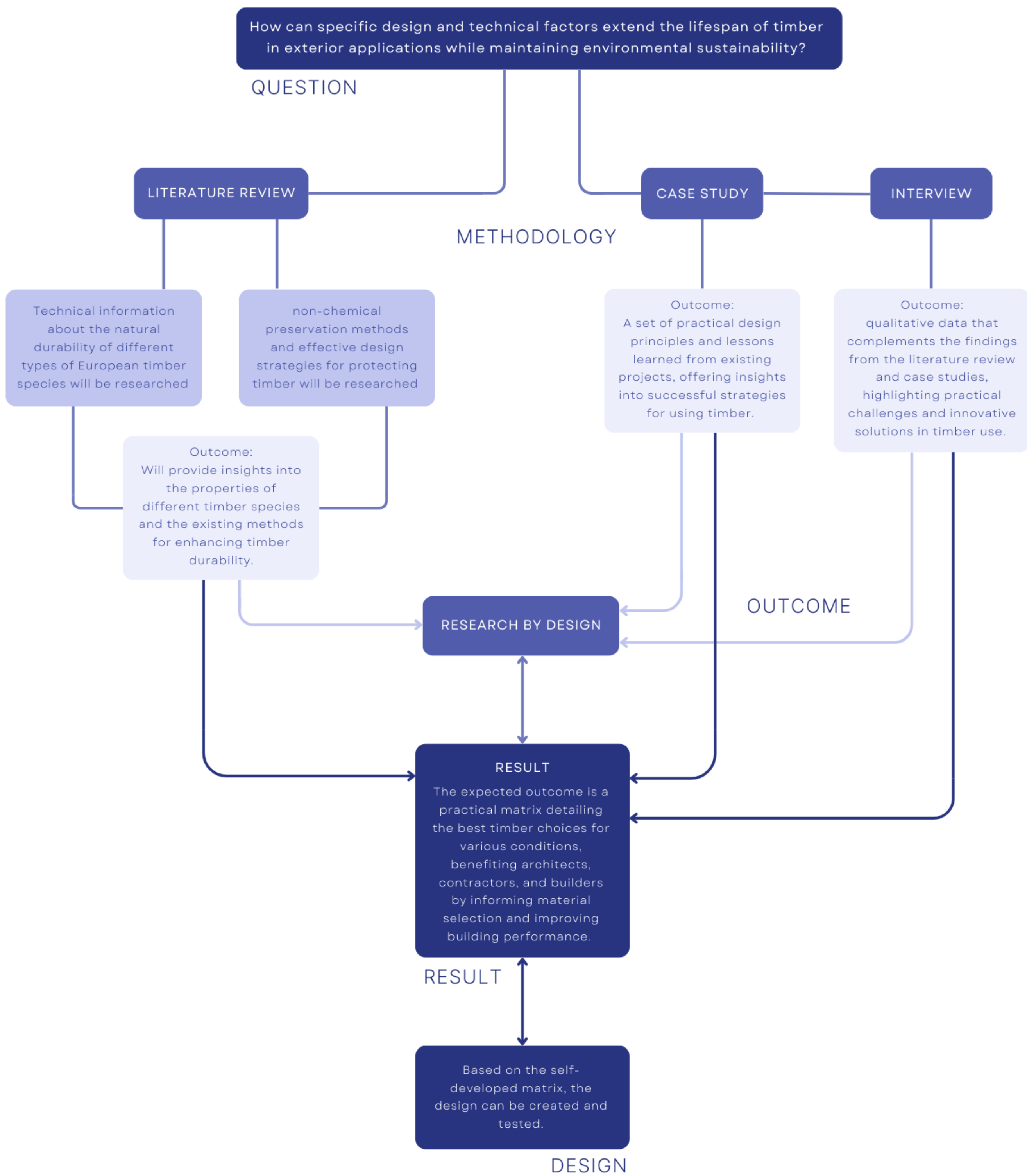
- Živković, V., Jones, D., Jones, D., Brischke, C., Bardage, S., Nunes, L., Palanti, S., Humar, M., Suttie, E., & Kutnar, A. (Reds.). (2017). *Building with Bio-Based Materials: Best practice and performance Specification*. University of Zagreb, Faculty of Forestry.

Research diagram



Planning

	P2												P3						P4														P5
	WEEK 2.1	WEEK 2.2	WEEK 2.3	WEEK 2.4	WEEK 2.5	WEEK 2.6	WEEK X	WEEK X	WEEK 2.7	WEEK 2.8	WEEK 2.9	WEEK 2.10	WEEK 3.1	WEEK 3.2	WEEK 3.3	WEEK 3.4	WEEK 3.5	WEEK 3.6	WEEK 3.7	WEEK 3.8	WEEK 3.9	WEEK 3.10	WEEK 4.1	WEEK 4.2	WEEK 4.3	WEEK 4.4	WEEK 4.5	WEEK 4.6	WEEK 4.7	WEEK 4.8	WEEK 4.9	WEEK 4.10	WEEK 5.1
Phase II_Exploration																																	
Detailed SWOT																																	
Sub-question 1																																	
Sub-question 2																																	
Sub-question 3																																	
Phase III_Evaluation																																	
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Phase IV_Creating																																	
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