Biobased tectonics

Transforming and densifying a post-war
neighborhood with industrial biobased elements

Biobased tectonics

Transforming and densifying a post-war neighborhood with industrial biobased elements

Keywords
Post war neighborhoods, Biobased materials, industrialized housing, adaptive housing, transformation

Research plan
Master of Science, Architecture, Urbanism & Building Sciences

Personal Information
Sanne Buser
5720338
Sanne.buser@gmail.com

Studio
Architectural engineering
Mo Smit
Pieter Stoutjesdijk

Choice for studio
The decision to choose the graduation studio in architectural engineering is motivated by the current transformation we must undertake within the contemporary building industry. There is a transition needed from the current linear building industry to a more circular economy with emission-free building techniques and renewable materials. What captivates my interest is the exploration of the integration of these novel techniques and materials within the pre-existing social and architectural context.

Content

Keywords

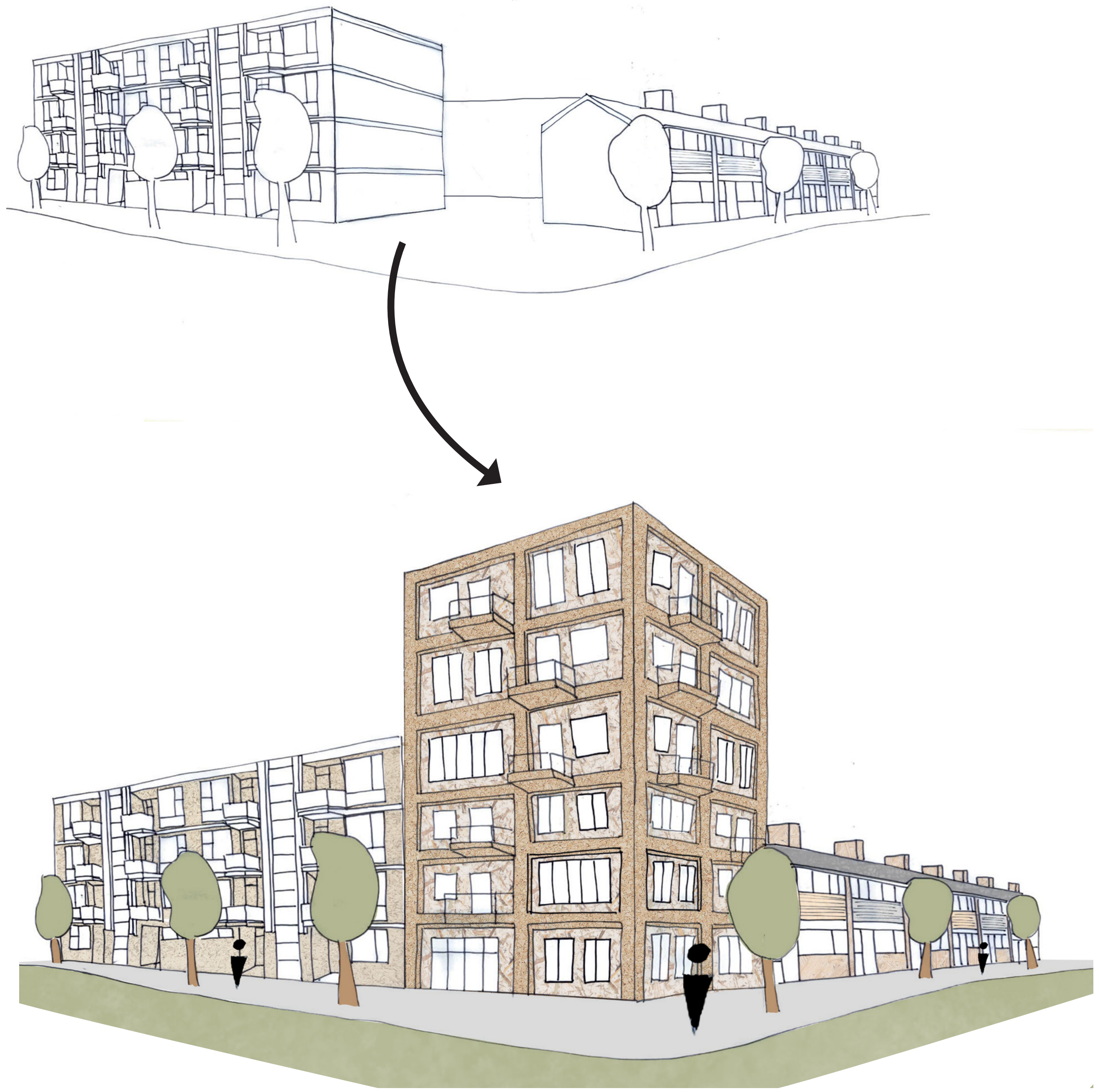
Adaptive housing: Refers to houses that are design and constructed to be flexible and easily adaptable to the changing needs and circumstances. These homes can accommodate varying family sizes, lifestyles or accessibility requirements over time.

Biobased materials: Biobased materials are substances derived from renewable resources form living matter, biomass. They either occur naturally or are synthesized.

Industrial elements: elements that are produced in a factory manner and assembled on the construction site. The elements are often created by machines or software.

Post-war neighborhood: residential areas built in the period after the Second World War from 1945-1985. These are often built on a former empty site.

Tectonics: is the relationship between structure materials and the aesthetics of a building. It involves the study and expression of the structural elements and construction methods, highlighting the assembly and composition of architectural forms.

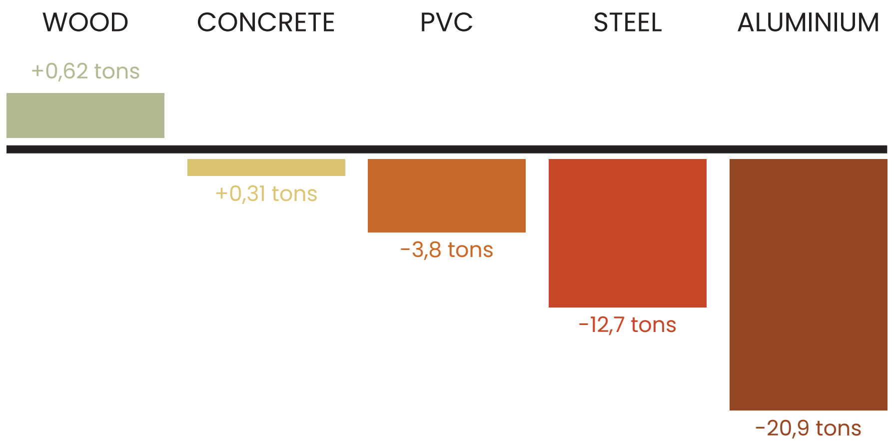


Existing neighborhood will be densified with a biobased building (inspired by: KAW, 2020)

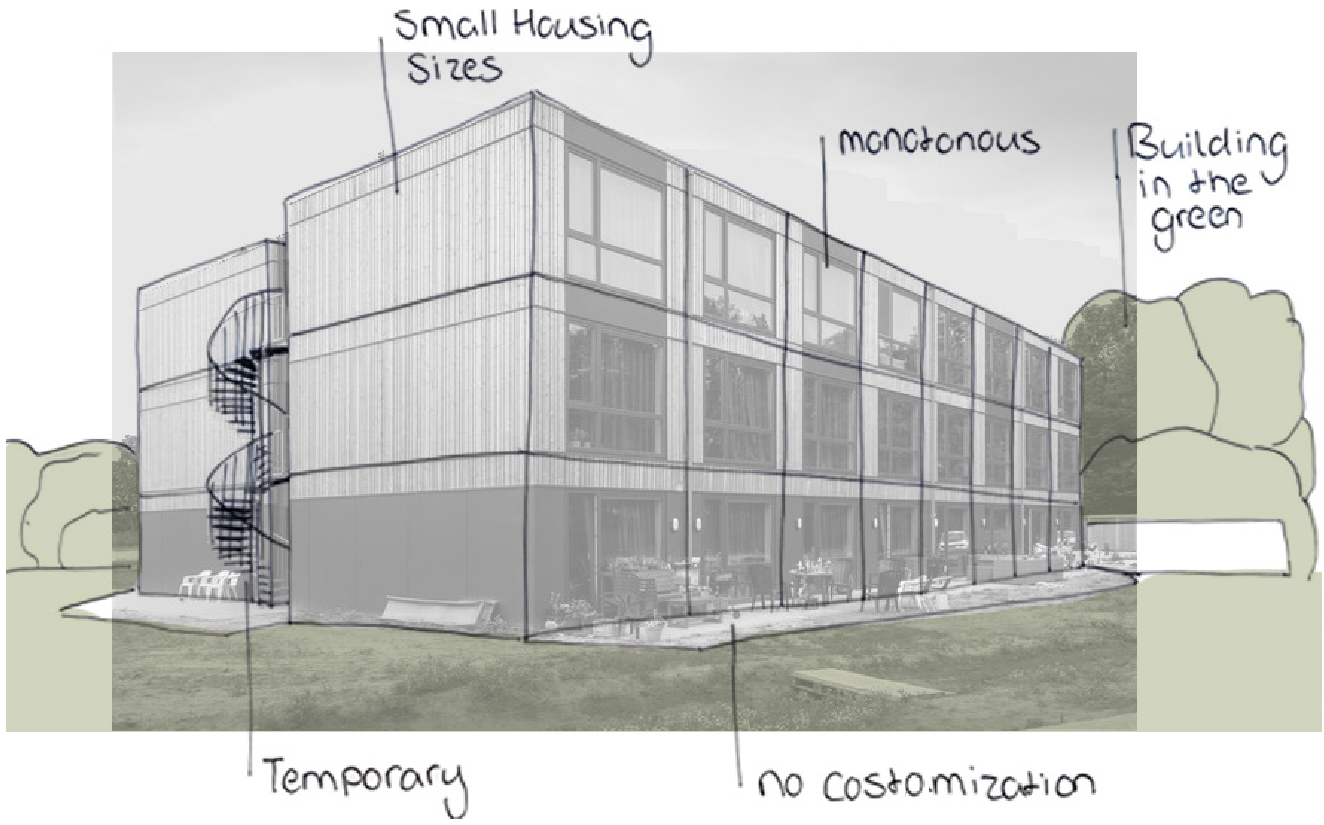
General problem statement

The construction industry is currently confronted with several significant challenges. Firstly, the industry must move away from traditional construction methods that are still prevalent.
The energy-intensive production of construction materials, such as cement and steel, and the fossil fuels used for construction machinery and transportation must be replaced by sustainable materials and new techniques. The current construction methods contribute to 40% of global CO_2 emissions, with material usage alone accounting for 11% of total global CO_2 emissions (Cityforster et al., 2022a). Furthermore, Key resources like sand and gravel, essential for cement production, are at risk of depletion. The pressure on the raw materials market is only expected to increase in the next three decades (Cobouw, 2023a). In addition, there is a deficiency in the integration of innovation. Technology has developed in the fourth industrial revolution, characterized by automation and data exchange utilized in industrial manufacturing techniques that can also be efficiently applied within the construction sector (McKinsey & Company, 2022). In conclusion, it is necessary to reconsider conventional construction materials and techniques.

Another issue in the contemporary construction sector is the housing shortage in the Netherlands. In 2023, the housing shortage has reached 390,000 homes, and it is projected to increase even further by 2028 (NOS, 2023a, RTL, 2023a). Among the reasons for this shortage, alongside population growth, is the change in household sizes. Nowadays, fewer people reside in each household, resulting in a induced need for housing (CBS & Jonkers, 2022, RTL, 2023a). A diverse range of housing options must be developed to accommodate various household compositions, offering opportunities for growth and downsizing. Currently, the housing market is stagnating due to a lack of diverse offerings and high housing prices.



Netto CO2 emissions from various building materials (Bruggink, 2020)



Disadvantages of flexhouses, flex houses in Den Bosch (Bolsius, 2022)

An attempt by the Minister of Internal Affairs, Hugo de Jonge, to address the short-term housing shortage is the acquisition of flexible housing units (NOS, 2023b). Despite the efficient way of production, with a short construction time less waste, production in better conditions and often use of biobased materials (INBO, 2021). These dwellings have their drawbacks, including the challenge of finding suitable locations, the often monotonous appearance of the units, their temporary nature, and the difficulty of customizing them to personal preferences (Van Laar, 2023), (RTL, 2023b). There is a need to construct more permanent housing units efficiently within existing contexts. But by using the efficient production method that is used in developing these flexible homes.

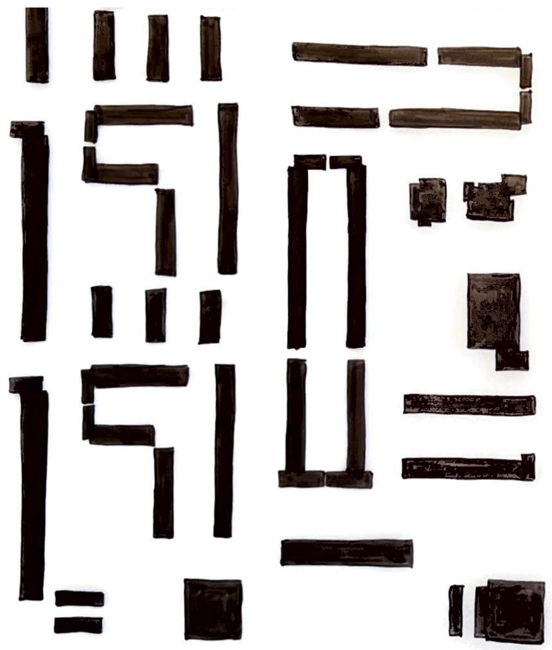
Finally, it is not only necessary to construct new sustainable homes, but also to modernize and improve the existing housing stock. By 2050, all existing homes must undergo sustainability enhancements (Ministerie van economische zaken en klimaat, 2022). A significant portion of the current housing stock dates back to the post-World War II era. In 2016, 35% of the housing stock was built between 1945 and 1965 (CBS, 2023). After the war, there was a housing shortage due to wartime destruction, decay, and anticipated population growth. In response, homes were rapidly and affordability produced, utilizing the innovative production methods of that time. The development of functional housing designs led to the mass production of affordable homes (Blom et al., 2014) (Hereijgers et al., 2001). The consequences of the rush in construction are now evident in the technical quality of these homes. Many of these homes suffer from low thermal and sound insulation, high energy consumption, and significant wood rot issues (Garritzmann Architects & hp architecten, 2015) (Ministrie van onderwijs, cultuur en wetenschap, and Science, 2021) (Hulsman, 2023). Quantifying the technical quality of the entire Boerhaavewijk is complex, given the various building types, different ways of ownership, and because a part of the northern side of the neighborhood has recently been redeveloped. Some of the homes have already been renovated, significantly improving their technical quality (Gemeente Haarlem, 2023).

The urban planning for these residential neighborhoods followed functional modernist principles aimed at providing the working class with spacious, healthy, and green living environments. Unlike closed city blocks from the pre-war houses, with a clear distinction between architecture and urban planning, these post-war neighborhoods were designed with an open layout. Because of this, they lack a clear distinction between architecture and urban planning, despite having a clear main structure and a green character (Hereijgers et al., 2001). As a result, an integrated solution must be sought when renovating neighborhoods in which public space plays an important role.

Furthermore, these areas often lack a balanced mix of functions and housing types, because the design followed the modernist principles of separating functions. The repetitive rhythm within the neighborhood results in a lack of diversity

Deteriorated public space post war neighborhood, (Boerhaavewijk, z.d.)

Urban structure in Haarlem centre



Urban structure in the Boerhaave neighborhood

and individual identity. Moreover, many of the residents experience social economic vulnerabilities, with twice as many individuals reliant on social assistance compared to the rest of the Netherlands, and often grappling with social issues in the neighborhoods (NOS, 2020, CBS, 2023). In conclusion, these neighborhoods have lost their appeal in recent times, deteriorating due to poorly maintained public spaces and inadequately insulated, outdated homes, rendering them unsuitable for modern energy and living standards. Architect Sjoerd Soeters therefore has proposed a comprehensive demolition and reconstruction approach (Hulsman, 2023), although alternative, sustainable methods should also be explored to transform these neighborhoods and restore their vitality.

Problem statement
The current construction methods are inefficient, reliant on scarce and non-sustainable materials, and result in substantial emissions. As a consequence, the construction industry is unable to quickly meet the present market demands, including addressing the housing shortage and the revitalization of various disadvantaged neighborhoods in the Netherlands.

To meet these demands effectively, the adoption of efficient construction techniques and sustainable materials is imperative. Opportunities exist in the densification of disadvantaged neighborhoods, enabling their revitalization and the creation of additional housing units that can help alleviate the housing shortage

Overall design objective

The aim of the graduation project is the revitalization of the post-war Boerhaave district in Haarlem, from a neighborhood with inadequate public spaces, and deteriorating housing conditions. The overarching aim is to metamorphose this district into a diverse and sustainable neighborhood that responds to contemporary housing demands through densification and sustainability. The district is being transformed through a set of elements that are produced in an industrialized emissive-friendly way and made from bio-based materials. Within the project, research is conducted on three different scales, enabling the development of an integrated design.

On the urban scale, a contextual analysis is done about the current housing stock, population, and historical value. A contextual analysis shows the current problems of the neighborhood, the demographic distribution, and the current housing types. Potential strategies will be sought to renovate and densify the neighborhood. Emphasis will be placed on enhancing spatial quality and ameliorating the overall energy and ecological systems of the area. The ultimate goal is to make a sustainable community characterized by spatial quality and social cohesion, thereby fostering a resilient and vibrant living environment for the future.

On the building scale, the current housing stock will have to change with a greater diversity of flexible homes, to accommodate the changing housing demands. An analysis of adaptive housing solutions will be done. This adaptability can ensure greater housing diversity, attracting a broader demographic range and, consequently, enriching the vitality of the neighborhood. A varied housing inventory ensures that houses are suited to meet the current and future market demands. In addition, a specific housing type within the neighborhood will be examined to see how it can be densified and transformed, creating a greater variety of flexible homes.

The scale of the elements is used to create a toolkit of elements that can be used in the renovation and densification of post-war neighborhoods. The toolkit consists of elements across multiple architectural layers, encompassing building structures, façades, and housing separations. These elements, constructed from bio-based materials, are produced industrially, with low-emission techniques, ensuring scalability and environmental sustainability throughout the transformation process.

The thematic research will focus on the development of a facade element, as a part of the toolkit. Using biobased materials that have been innovative in comparison to contemporary construction methods. Designers do not yet know how to optimally use these materials in the design. The thematic research is therefore about how a total assembly can be put together in which all materials are used as optimally as possible. The strongest properties of each material are used for the function it needs. The research findings provided designers with valuable insights into the optimal integration of bio-based materials within facade compositions.

Ultimately, a principal design will be made for a repeating stamp that is used to design the Boerhaave district. This stamp design will encompass design principles for public spaces, energy, and ecological dynamics, the mix of functions, and densification principles. Within this plan, a building type is transformed, where the adaptive and densification strategies are worked out in greater detail. The building is being technically improved. All use the elements from the developed toolkit.

The overarching aspiration is to contribute to a more sustainable, affordable, and appealing living environment within Boerhaave Haarlem. This is to be achieved, through the development of innovative design solutions, which may serve as a model for addressing similar challenges in post-war residential districts worldwide.
solutions, which may serve as a model for addressing similar challenges in post-war residential districts worldwide.

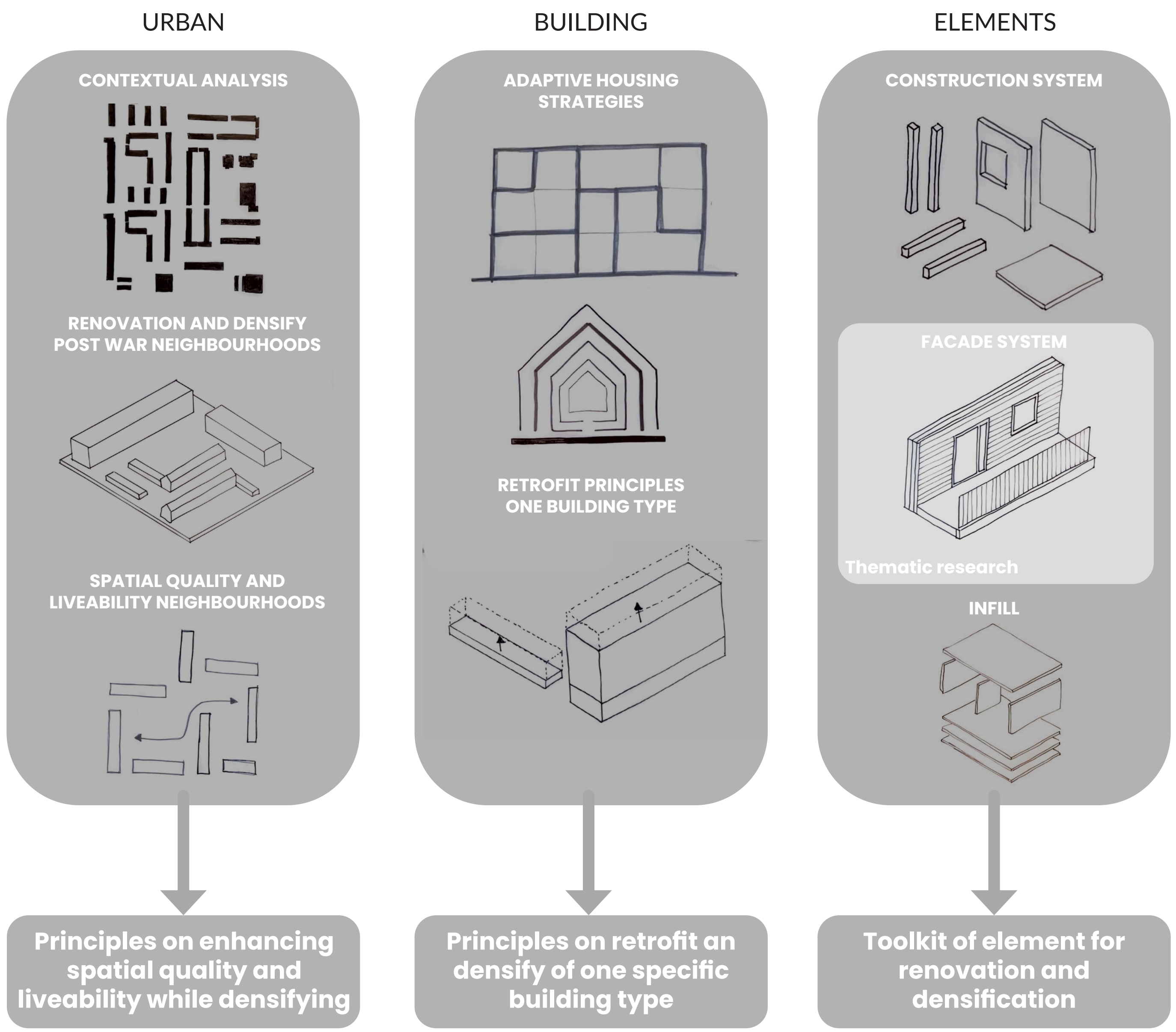


Diagram with themes across the different scales (own work)

Design questions

How can the densification and retrofit of post-war neighborhood Boerhaave, by adding diverse and adaptive housing structures using prefabricated industrial biobased building methods, contribute to revitalizing and redefining the identity of the neighborhood?

Sub design questions

1. How can the Boerhaave neighborhood be densified, while simultaneously enhancing its spatial quality and livability?
2. How can diverse housing units be incorporated into the Boerhaave neighborhood, with adaptive strategies, both within existing structures and new constructions?
3. What prefabricated industrial biobased building methods can be used to create components (building structures, facades, housing separations) for housing structures that can both refurbish existing structures and realize new buildings?

Reflection on relevance

The design challenge of densifying, revitalizing, and restoring the identity of the Boerhaave neighborhood seeks a specific solution for this community. Nevertheless, the methods and design principles employed may concurrently serve as a source of inspiration for the transformation of other post-war residential areas. This transformation not only holds significance for the end-users but also carries societal importance, contributing to the transformation of post-war neighborhoods into diverse and vibrant communities, thus promoting resilience.

Furthermore, the densification of the neighborhood offers a solution to the housing shortage in the Netherlands. Different opinions have emerged regarding the potential number of housing units that can be added through densification in these areas. In the study *Ruimte zat in de stad* by KAW Architects, an investigation was conducted into the available spatial capacity within existing urban areas for accommodating new housing units. It was found to be feasible to create 500,000 to 700,000 additional housing units in 1,800 post-war neighborhoods (KAW Architects, 2020). Friso de Leeuw, a professor of urban development at Delft University of Technology, contends that this is an overestimation. While there is undoubtedly available space in post-war neighborhoods, one should consider themselves fortunate if it is possible to realize 100,000 additional housing units (Nebbeling, 2021). In the research conducted by Jeffery Bolhuis, a design study was made for Schalkwijk, of which Boerhaave is a constituent part. The study revealed that approximately 2.200 additional housing units can be accommodated in the district of Schalkwijk (AP+E & Studio dmau, 2022). The precise number of housing units that can be feasibly added in these neighborhoods remains a subject of discussion. Nevertheless, there is acknowledgment that there is potential for new housing units in these areas.

The design of a housing system utilizing industrial biobased construction methods has the potential to offer a generic solution applicable not only to post-war neighborhoods but also to other transformation and new construction projects. The adaptability of this system enables its use in various project types and provides valuable insights into the optimal integration of sustainable building materials and efficient construction techniques within architecture.

Design research methodology

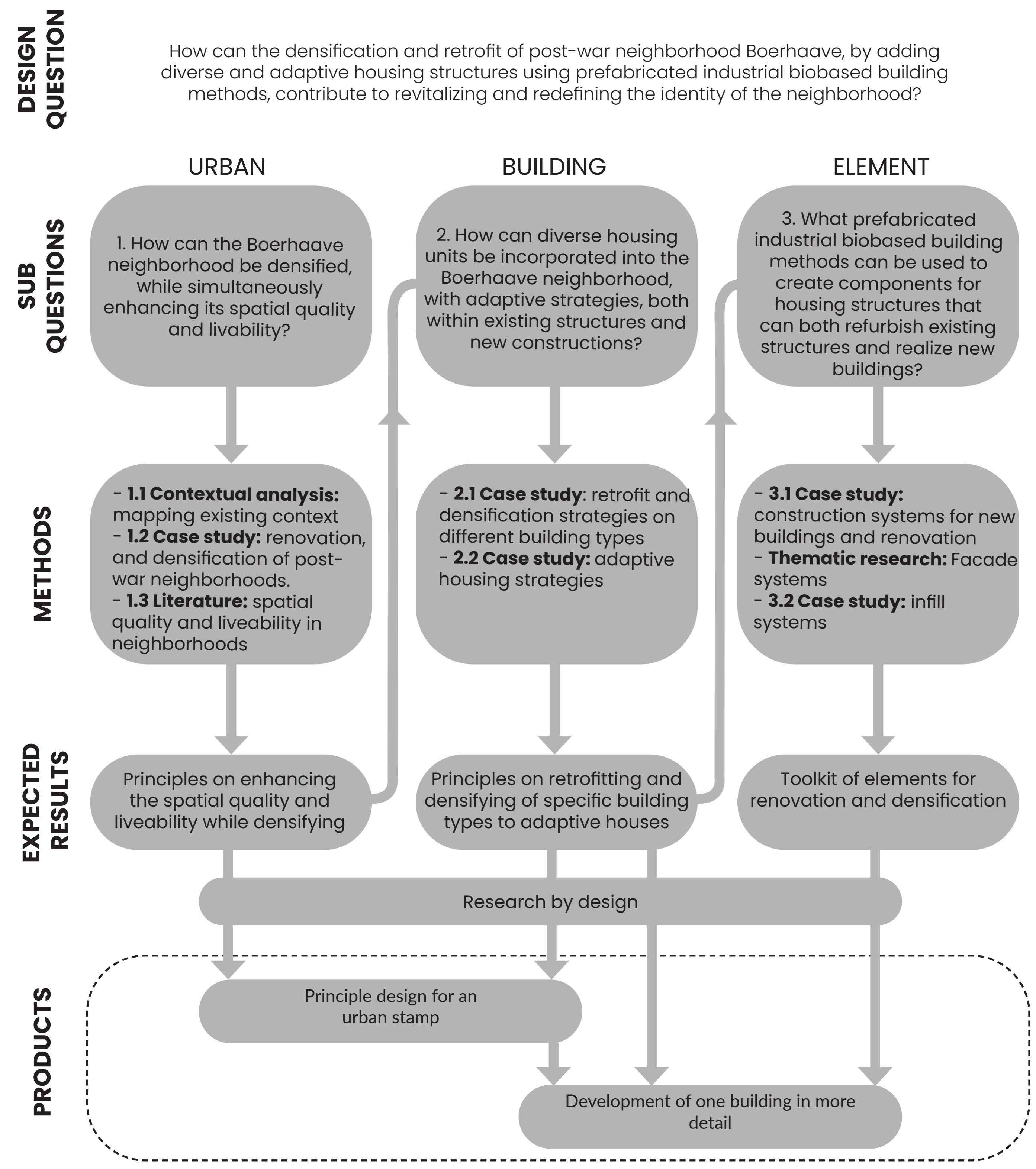


Diagram with questions, themes and products from the design research (own work)

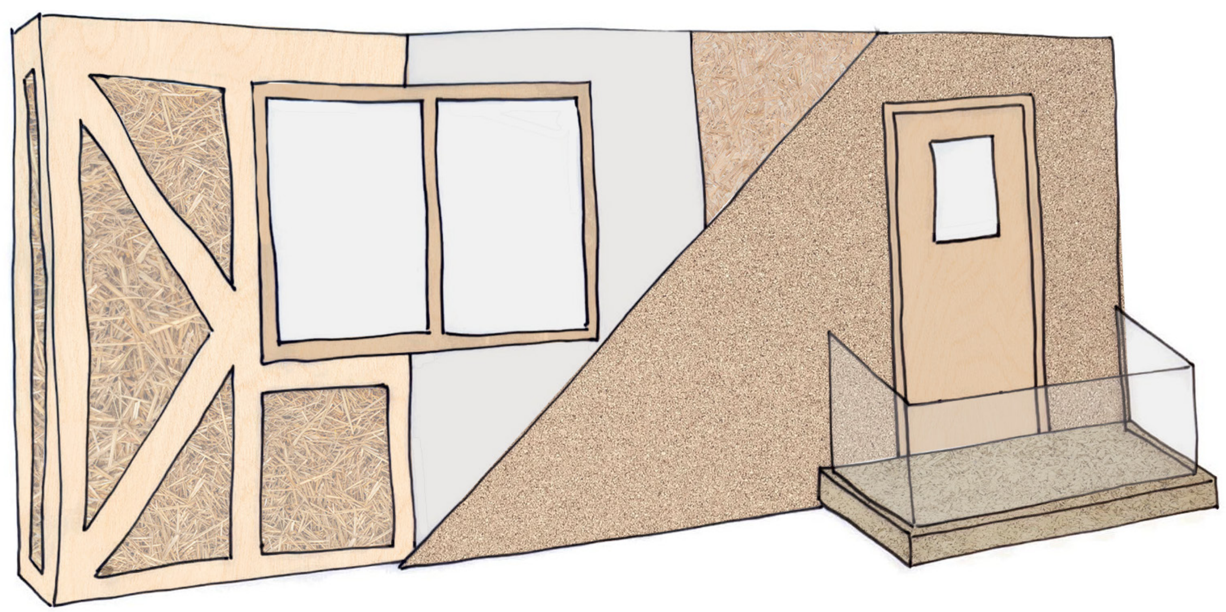
Potential transformation of a street in the Boerhaave neighborhood (own work)

Thematic research

Thematic research objective
The contemporary construction industry needs to reconsider conventional construction materials and techniques that leave a significant ecological footprint. Resource depletion and high CO2 emissions are inherent to the current production of construction materials (Cityfoster & De circulaire bouweconomie, 2022b). Therefore, the use of biobased materials derived from renewable sources is a sustainable alternative that is becoming increasingly important.

Nevertheless, construction companies often perceive the use of biobased materials as risky and costly, primarily because these materials are currently manufactured by small businesses that cannot compete with the large-scale production prevalent in the construction sector. The new materials require new certificates and must be tested to determine whether they comply with the regulations.(Circulair Zuid Holland, 2021) (EIB, 2017). There is a pressing need to investigate how biobased materials can be industrially and sustainably produced on a scalable basis.

New industrialized construction methods are under development but have not been fully integrated into the current construction industry. Architects must adopt a new role and rethink the techniques and materials to be used. Tectonic thinking, which revolves around the comprehension of the nature and properties of materials, construction methods, and techniques, and how these are integrated into architectural design, is essential according to Anne Beim (2013).



Facade system consisting of various biobased elements (inspired by: strotec, 2023)

Tectonic thinking can refine and identify the evolution of the current construction industry toward greater use of industrial processes and techniques. Creative imagination is required in considering how a product can be further incorporated into a comprehensive system (Beim, 2013). New techniques and systems can contribute to functionality and aesthetics in other ways, giving a fresh perspective. Additionally, tectonic thinking can harmonize a building with its natural surroundings through ecological tectonics, which involves a profound understanding of the nature of materials and techniques. It clarifies the suitability of materials and techniques for fitting a building within its specific ecological, social, and cultural context, which is crucial for maintaining the ecological balance in an aesthetically pleasing manner (Beim, 2019).

Remaining abreast of new production techniques, systems, and materials is imperative for tectonic thinking since these innovations offer new possibilities for creative and efficient architectural designs. Designers must acquire knowledge about the properties and applications of biobased materials and new techniques to effectively integrate them into architectural practice. This allows architects to make informed decisions where technology, aesthetics, and functionality can converge.

Thematic research question
How can an industrial biobased facade element for the Boerhaave neighborhood be developed with the product development methodology in which the properties of the materials are used optimally and at the same time the designer has the freedom to give the facade a certain identity?

Thematic sub-questions
1. Which facade compositions are found in the Boerhaave neighborhood and retrofit projects of post-war neighborhoods, and what architectural elements do they consist of?
2. What criteria ensure that the facade system is functional, sustainable and allows architectural expression, and how can these be made measurable?
3. What types of biobased facade systems are available for both retrofit and new construction, and of which elements do the consist ?
4. What biobased materials and elements exist that can be industrially produced, and to what extent do they meet the established criteria?
5. How are the various alternatives of biobased materials quantified according to the predetermined criteria?

Reflection on relevance
The research is generic, focusing on the collection and insight of biobased materials produced through industrial techniques. The ultimate outcome of the study provides an overview of various biobased materials and their properties, along with how these materials can be efficiently and sustainably applied in a facade system. Designers can extract from the overview, with project-specific criteria based on; context, culture, functionality, aesthetics, cost, sustainability, or history, which materials align with their requirements. This approach facilitates the optimal utilization of materials, allowing for the maximization of their inherent strengths within the design. In addition, the overview also offers the designer freedom, because it immediately becomes clear what the strengths and weaknesses of each material are, the designer can combine them in a creative and infinitive way for the desired result.

Thematic research methodology

The primary research methodology for the thematic research is a product design methodology. This approach provides a structured framework for the design process, accommodating numerous possibilities. It involves breaking down the design problem into smaller sub-problems, for which partial solutions are developed, ultimately leading to a comprehensive solution (Mac-Lean, 2018) (Van Veen, 2016).

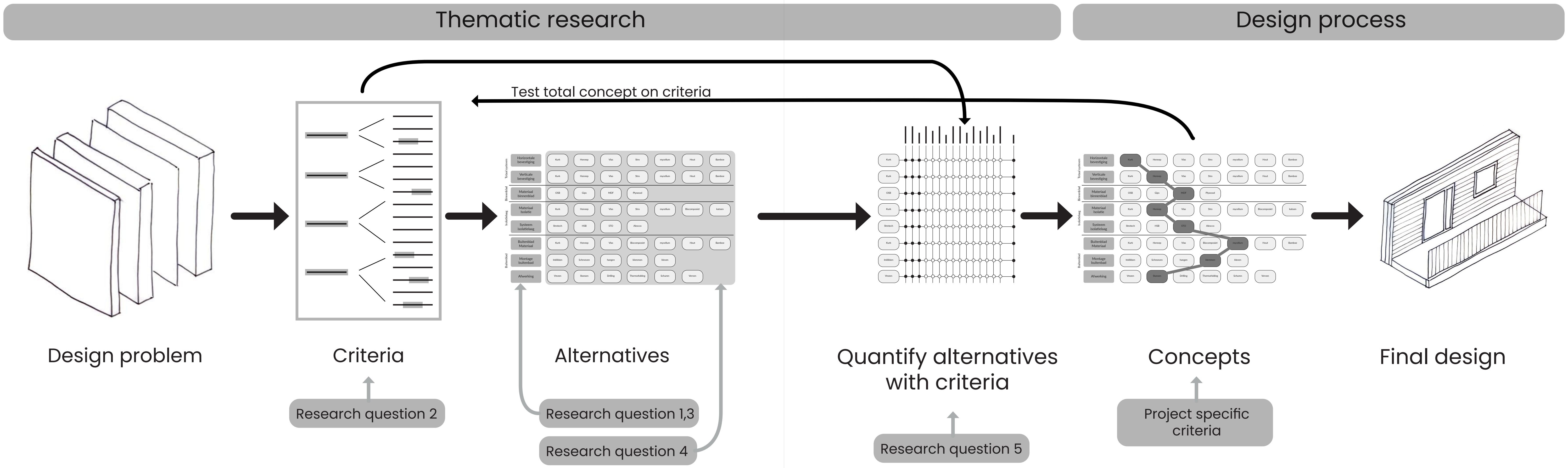
The design challenge revolves around gaining insights into the most suitable materials for each component within a façade system. In the first sub-question of the research, an examination will be conducted to identify the various elements constituting the facades in the existing Boerhaave neighborhood. Additionally, an analysis will determine which elements contribute to the neighborhood's identity and whether they should be retained or if the neighborhood should acquire a new identity.

Subsequently, criteria for the entire façade system will be defined, along with methods for quantifying them. The primary criteria for the façade elements are sustainability and architectural freedom, with corresponding sub-criteria to be discussed in the following section. The relevance of specific criteria may vary for each element; for instance, the Rc-value is not a decisive criterion for exterior cladding but is crucial for the insulation layer.

By addressing sub-questions three and four, various alternatives can be explored. Sub-question three investigates existing façade systems and offers insight into the different components within this system. Sub-question four provides an understanding of various biobased materials and techniques that can be utilized in producing these elements, as well as their compatibility with the criteria outlined in sub-question two. From this, a table can be constructed, outlining the various components within a complete façade system and listing all the different materials and techniques for each component, referred to as alternatives.

To make specific choices based on the predefined criteria, all these alternatives will be quantified. The information about these alternatives obtained in response to sub-question three will be presented in a new table, allowing for easy comparison of all alternatives for each façade component. A table will be established for each façade component, serving as the final product of the thematic research.

These tables will help by making specific material choices in the design process. Project-specific criteria, including building type, context, and the architectural identity the designer intends to convey, will determine which alternatives are selected. All the alternatives together form a concept, which will be subsequently evaluated against the criteria, enabling a re-evaluation of choices. If the combination of alternatives aligns with the project-specific and general criteria, it can be incorporated into the final design.



Research methodology (Van Veen, 2016)

Expected results
The research aims to gain more knowledge for the use of biobased industrial materials in façades. First, an analysis of existing facade systems, facades in the Boerhave context and retrofit facade solutions is done. Through this analysis, diverse facade elements will be defined that can be combined into a comprehensive facade system. Additionally, an exploration of various industrial biobased materials will be conducted, and these materials will be quantified based on a predefined set of criteria. Consequently, the expected outcome will encompass a comprehensive overview detailing the optimal material choices for each specific type of facade element.

The anticipated results of this thematic research will form a framework for designers, enabling the selection and integration of biobased materials into facade systems that not only demonstrate sustainability but also provide the flexibility needed for architectural creativity. Designers will be equipped with invaluable insights to make informed decisions regarding the optimal incorporation of biobased materials within facade systems.
The central criterion of architectural flexibility empowers designers to use their creative ingenuity to achieve the desired outcomes while meeting project-specific criteria. The research tries not only to address the specific requisites of the Boerhaave neighborhood but also possesses the potential to influence transformation and densification projects. While the chosen elements within the framework are intricately tailored to the renovation and densification of a post-war residential district, their applicability extends to systems for diverse building typologies.

In the research's concluding phase, an evaluation will be undertaken to assess the efficiency of the applied methodology and the usability of the results within design processes. Subsequently, in the design task that promptly follows the thematic research, the framework will be promptly applied, facilitating the concurrent design of a comprehensive facade system.

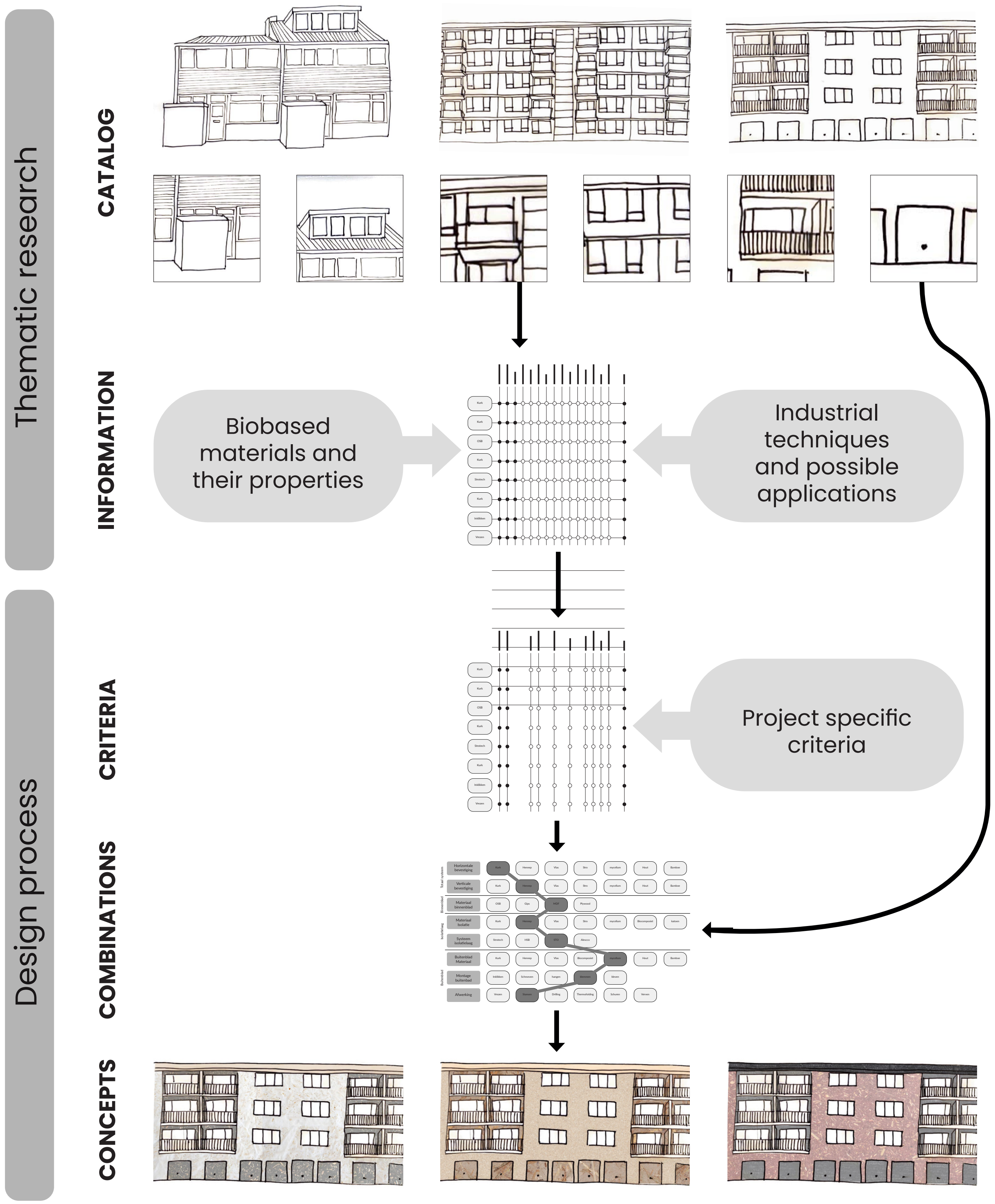
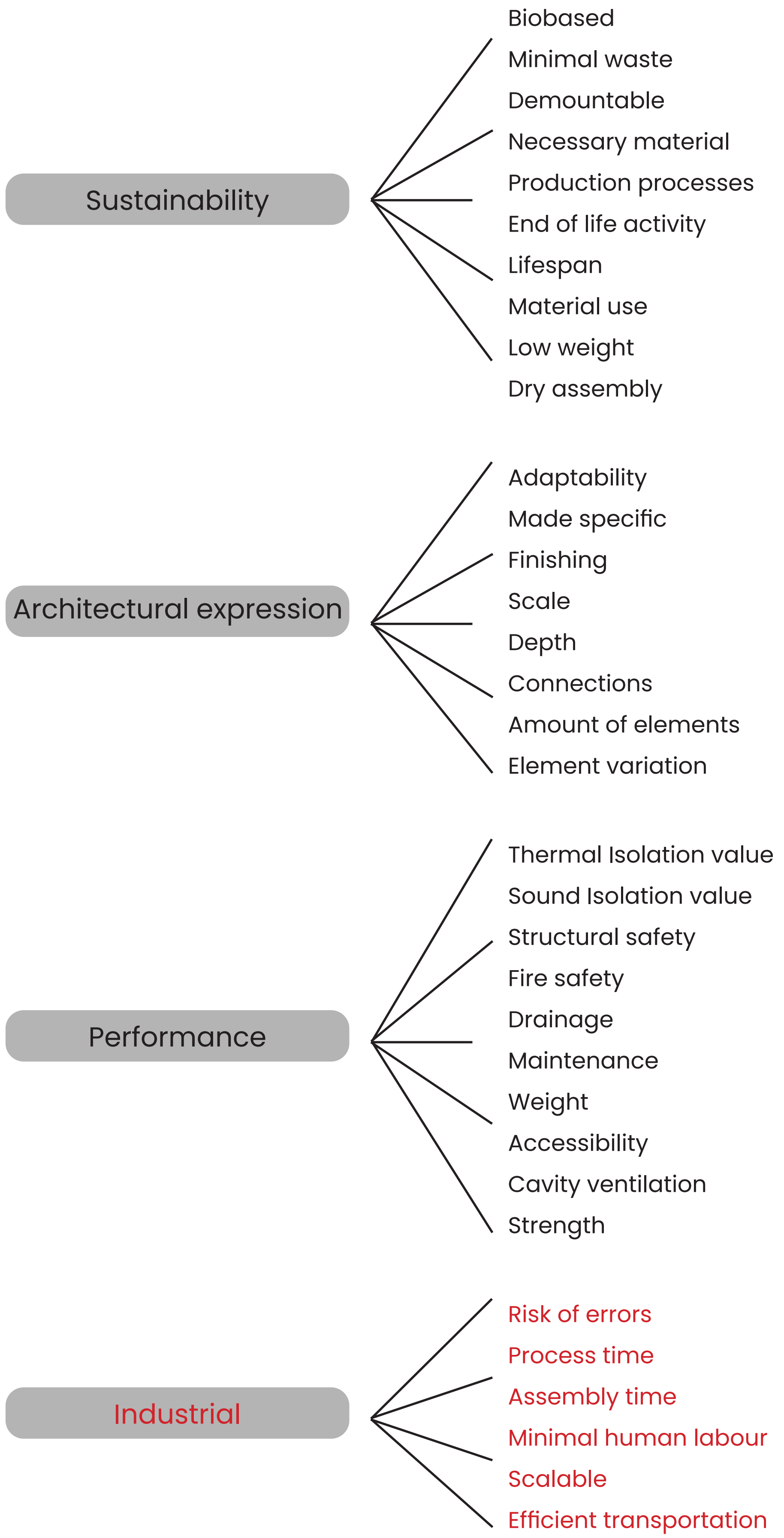


Diagram with insight into the thematic research and the application for the design process (own work)

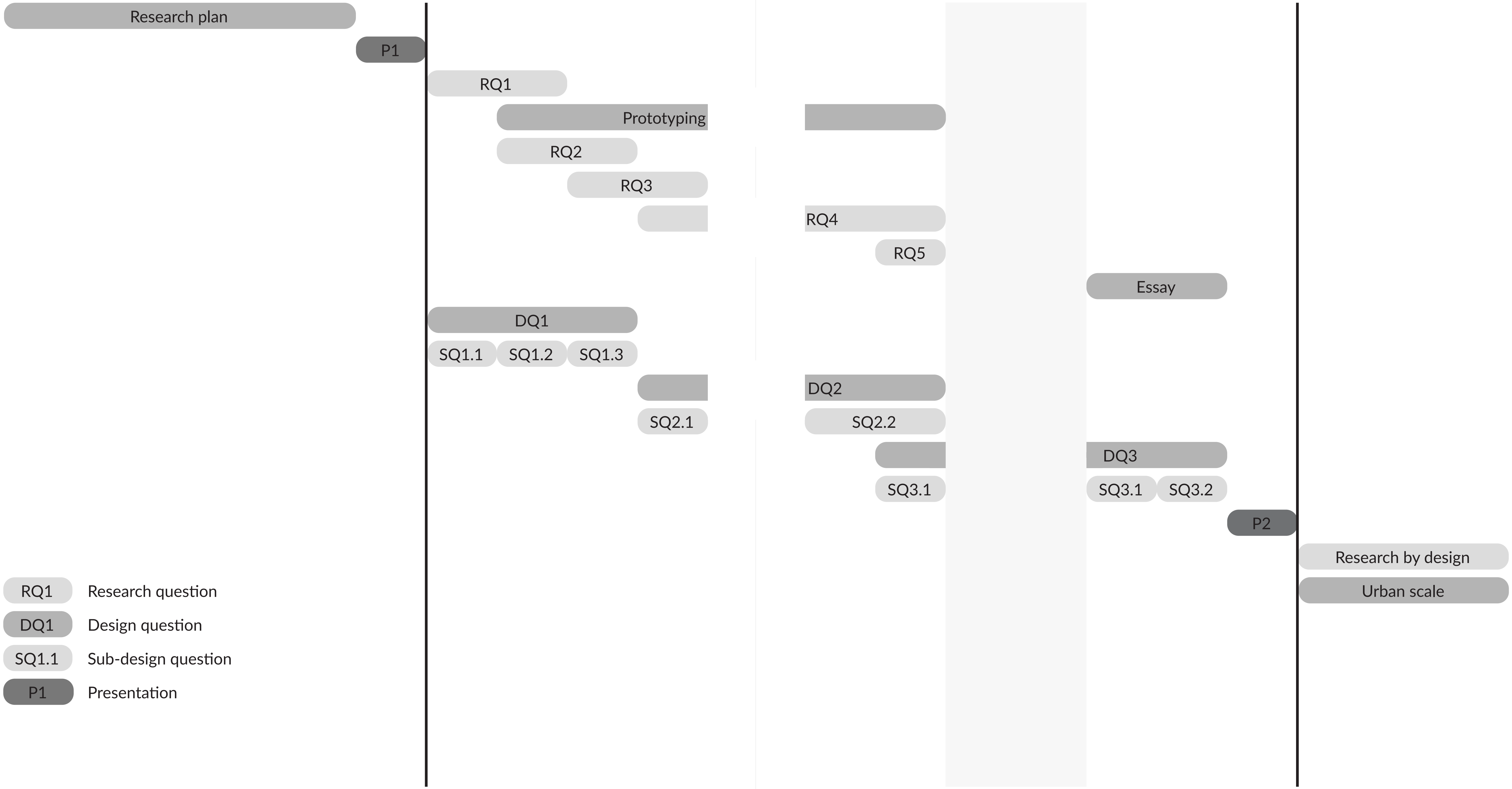
Criteria
To assess the various elements, criteria need to be established. These criteria are made measurable in the second thematic research question, allowing for comparisons. Although every project has project-specific criteria, four main criteria are presently identified that elements must adhere to sustainability, performance, and architectural expression. Derived from these overarching criteria, various sub-criteria are delineated for quantifiable evaluation. The sustainability criteria are all criteria that reduce the ecological footprint of the building but also reduce the energy requirement of the building but the most important criteria is that the element must consist of biobased materials. The performance criteria vary greatly per element and concern the functional properties, whether the element must be waterproof or it has a constructive function. The criteria for architectural expression must make the building attractive, the criteria now mentioned concern each element. But it is also important to look at the total composition of elements for architectural expression. Another important criteria arises from the main question that states that an industrial biobased facade element must be composed. Several sub-criteria have also been drawn up that can provide insight into how effective the production method is.



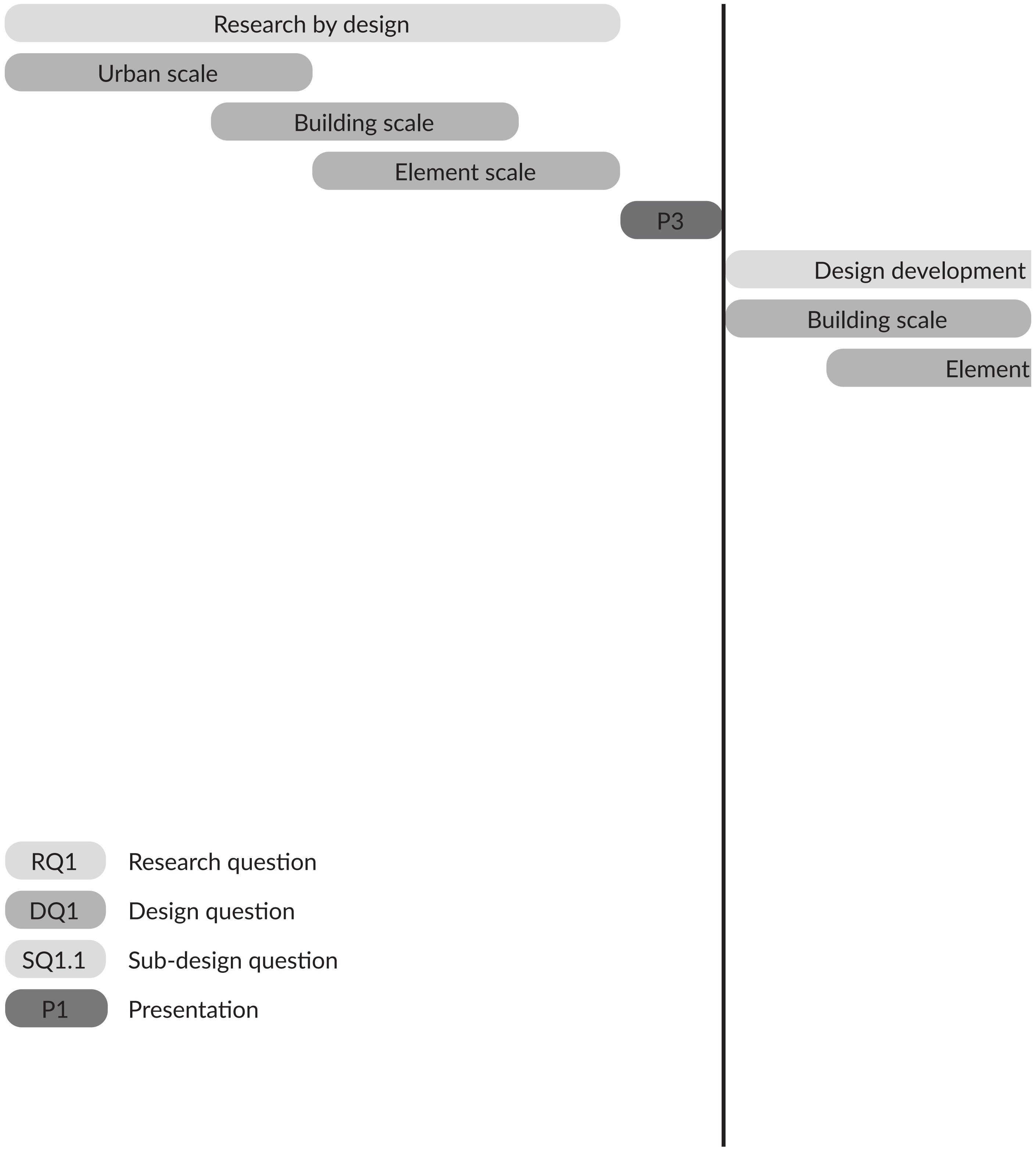
Planning

OKTOBER					NOVEMBER				
40	41	42	43	44	45	46	47	48	49
1.5	1.6	1.7	1.8	1.9	1.10	2.1	2.2	2.3	2.4

DECEMBER			JANUARY					FEBRUARY	
50	51	52	01	02	03	04	05	06	07
2.5	2.6			2.7	2.8	2.9	2.10		3.1

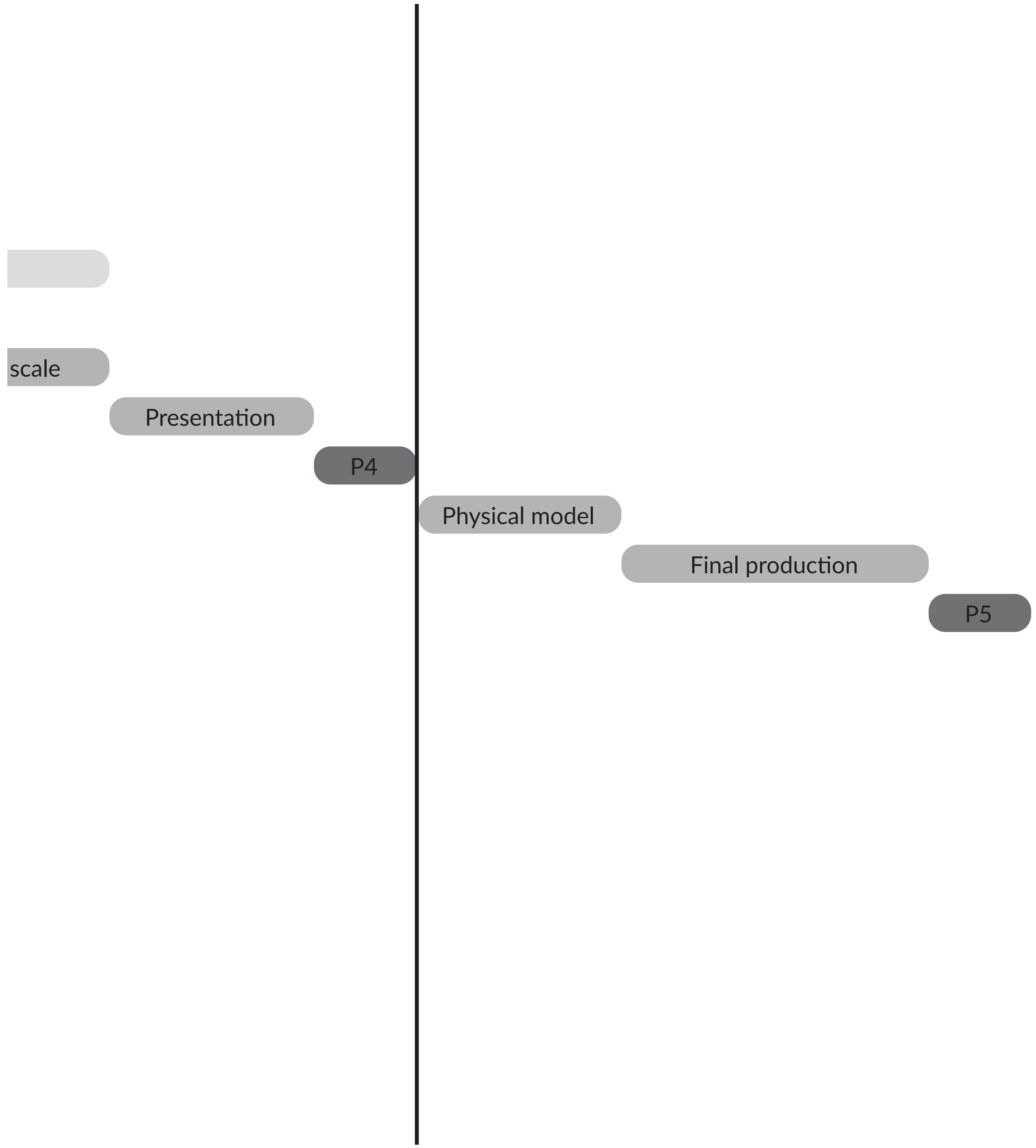


FEBRUARY		MARCH				APRIL			
08	09	10	11	12	13	14	15	16	17
3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	3.10	4.1



- RQ1 — Research question
- DQ1 — Design question
- SQ1.1 — Sub-design question
- P1 — Presentation

	MAY				JUNE				JULY
18	19	20	21	22	23	24	25	26	27
4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9	4.10	5.1



References

AP+E & Studio dmau. (2022). Living lab boerhaave [Dataset].

Beim, A. (2013). Tectonic thinking in contemporary industrialized architecture. DOAJ (DOAJ: Directory of Open Access Journals). https://doi.org/10.7480/jfde.2013.1-2.650

Beim, A. (2019). Tectonic Ecologies in Architecture – A Critical perspective in a time of transition. In CRC Press eBooks (pp. 11–27). https://doi.org/10.1201/9781315229126-3

Blom, a, Jansen, van der Heiden, M., & Rijksdienst voor monumentenzorg. (2014). De typologie van de vroeg-naoorlogse woonwijken. https://www.cultureelerfgoed.nl/binaries/cultureelerfgoed/documenten/publicaties/2014/01/01/de-typologie-van-de-vroeg-naoorlogse-woonwijken/typologie-van-de-vroeg-naoorlogse-woonwijken.pdf

Boerhaavewijk. (z.d.). Picture of Boerhaave neighborhood. Boerhaavewijk.nl. https://boerhaavewijk.nl/fotos/

Bolsius, M. (2022, januari). Flexwoningen uin Den Bosch. BD. https://www.bd.nl/oss-e-o/flexwoningen-voor-spoedzoekers-ruwaard-aanvullingen-op-plan-om-onvrede-weg-te-nemen-br-br~ac222f67/?referrer=https%3A%2F%2Fwww.google.com%2F

Bruggink, G. (2020, 17 september). Emissieloos bouwen doe je met hout. ORGA architect. https://www.orga-architect.nl/nieuws/emissieloos-bouwen-met-ecologische-houtbouw/

CBS, & Jonkers, H. L. W. (2022). 3. Demografische ontwikkelingen en de woningvoorraad. Centraal Bureau voor de Statistiek. https://www.cbs.nl/nl-nl/longread/de-nederlandse-economie/2022/achtergrond-bij-de-huizenprijsstijgingen-vanaf-2013/3-demografische-ontwikkelingen-en-de-woningvoorraad

Centraal Bureau voor de Statistiek. (2023, 8 september). Naoorlogse stadswijken. https://www.cbs.nl/nl-nl/nieuws/2017/46/veel-naoorlogse-stadswijken-sociaaleconomisch-zwak/naoorlogse-stadswijken

Circulair zuid holland. (2021). Biobased bouwen. https://ce.nl/wp-content/uploads/2021/02/CEDelft_PZH_Biobased-bouwen_def.pdf

Cityforster, Rijksdienst voor ondernemend Nederland, & De circulaire bouweconomie. (2022a). Carbon based design, onderzoek naar de milieu impact van de woningbouw. In circulairebouweconomie.

Cityfoster & De circulaire bouweconomie. (2022b). Carbon based design : Onderzoek naar de milieu-impact van de woningbouw. In De circulaire bouweconomie.

Cobouw, & de leeuw, M. (2023a, februari). Bouwkosten stegen in 2022 historisch hard en blijven in 2023 stijgen. Cobouw. Geraadpleegd op 19 september 2023, van https://www-cobouw-nl.tudelft.idm.oclc.org/310957/bouwkosten-stegen-in-2022-historisch-hard-en-blijven-in-2023-stijgen

Cobouw. (2023b, april). Zijn er genoeg grondstoffen voor de bouw van 900.000 woningen? Geraadpleegd op 26 september 2023, van https://www-cobouw-nl.tudelft.idm.oclc.org/304105/zijn-er-genoeg-grondstoffen-voor-de-bouw-van-900-000-woningen

Cobouw. (2021, november). In de stad is volgens deze architect wél plaats voor 1 miljoen woningen. https://www-cobouw-nl.tudelft.idm.oclc.org/300160/in-de-stad-is-volgens-deze-architect-wel-plaats-voor-1-miljoen-woningen

eib. (2017). Innovatie voor in de bouw. https://www.eib.nl/pdf/Rapport_Innovatie_in_de_bouw_web.pdf

EPA. (2010). Biobased materials. Epa. https://cfpub.epa.gov/si/si_public_record_report.#:~:text=Description%3A,by%20processes%20that%20use%20biomass.

Garritzmann Architecten & hp architecten. (2015). Kansen voor de naoorlogse portiekflat. https://www.hparchitecten.nl/wp-content/uploads/2019/10/Kansen-voor-de-naoorlogse-portiekflat.pdf

Gemeente Haarlem. (2023). GeoServer Haarlem - OpenData [Dataset]. https://kaart.haarlem.nl/app/map/45

Hereijgers, A., Pflug, M., & Van Velzen, E. (2001). De naoorlogse stad: een hedendaagse ontwerpopgave.

Hulsman, B. (2023, 13 september). Architect Sjoerd Soeters: 'Sloop de wijken uit de wederopbouwtijd'. NRC. https://www.nrc.nl/nieuws/2023/09/12/architect-sjoerd-soeters-sloop-de-wijken-uit-de-wederopbouwtijd-a4174212

INBO. (2021). Cross laminated timber, handboek voor architecten en bouwkundigen. In Inbo. https://inbo.com/nl/topics/inbo-clt-handleiding/

KAW architecten. (2020). Ruimte zat in de stad. https://www.kaw.nl/projecten/onderzoek-ruimte-zat-corporatievastgoed/

Mac-Lean, M. (2018). PD LAB: The development of a biobased cladding system. Master Student thesis, TU Delft, Delft.

McKinsey & Company. (2022, 17 augustus). What are Industry 4.0, the Fourth Industrial Revolution, and 4IR?. McKinsey & Company. https://www.mckinsey.com/featured-insights/mckinsey-explainers/what-are-industry-4-0-the-fourth-industrial-revolution-and-4ir

Ministerie van Economische Zaken en Klimaat. (2022, 4 februari). Gebouwde omgeving. Klimaatakkoord. https://www.klimaatakkoord.nl/gebouwde-omgeving

Ministerie van Onderwijs, Cultuur en Wetenschap. (2021, 17 maart). Upgraden van naoorlogse woningen. Wederopbouw | Rijksdienst voor het Cultureel Erfgoed. https://www.cultureelerfgoed.nl/onderwerpen/wederopbouw/upgraden-van-naoorlogse-woningen

Nebbeling, J. (2021, 30 november). Gooi de naoorlogse wijken op de schop en je krijgt er een miljoen woningen bij, zegt deze architect. NRC. https://www.nrc.nl/nieuws/2021/11/29/woningtekort-vernieuw-de-wederopbouwwijk-2-a4067259

nibe. (2019). Potentie van biobased materialen in de bouw. https://circulairebouweconomie.nl/wp-content/uploads/2019/07/CBE-Eindrapportage-potentie-biobased-materialen-NIBE-juli-2019.pdf

NOS. (2020, 3 februari). Minister wil betere mix van bewoners in achterstandwijken. NOS. https://nos.nl/artikel/2321430-minister-wil-betere-mix-van-bewoners-in-achterstandwijken

NOS, & Kraniotis, L. (2021, 17 februari). Schreeuwend tekort aan woningen, wat moet eraan gedaan worden? NOS. https://nos.nl/artikel/2369109-schreeuwend-tekort-aan-woningen-wat-moet-eraan-gedaan-worden

NOS. (2022, 18 oktober). "Straat bijbouwen in elk dorp en stad lost woningcrisis op". NOS. https://nos.nl/artikel/2448868-straat-bijbouwen-in-elk-dorp-en-stad-lost-woningcrisis-op

NOS. (2023a, juli 12). Woningtekort stijgt fors naar 390.000, pas vanaf 2028 minder krapte. NOS. https://nos.nl/artikel/2482485-woningtekort-stijgt-fors-naar-390-000-pas-vanaf-2028-minder-krapte

NOS. (2023b, mei 10). Nog veel geplande flexwoningen ongebouwd, buurt maakt vaak bezwaar. NOS. https://nos.nl/artikel/2474580-nog-veel-geplande-flexwoningen-ongebouwd-buurt-maakt-vaak-bezwaar

RTL. (2023a, juli 12). Te weinig nieuwe huizen, te veel mensen: woningtekort loopt op. RTL Nieuws. https://www.rtlnieuws.nl/economie/life/artikel/5395591/primos-prognose-2023-abf-woningtekort

RTL, (2023b, 8 augustus). Nog voor 190 miljoen aan flexwoningen in opslag ministerie. RTL Nieuws. https://www.rtlnieuws.nl/economie/artikel/5400583/er-staan-voor-190-miljoen-aan-flexwoningen-opslag-ministerie

Strotec. (2023, 6 november). Optimaal woongenot met de biobased Strotec gevel - Strotec. https://www.strotec.nl/producten/strotec-gevel/

Van Laar, D. (2023). Modulair bouwen: snel, betaalbaar en duurzaam. IGG Bouweconomie. https://www.igg.nl/kennisbank/trends/modulair-bouwen-snel-betaalbaar-en-duurzaam/

Van Veen, J. (2016). PD_LAB: A File-to-Factory envelope. Master Student thesis, TU Delft, Delft.