Designing Responsive Architecture Using Transformable Bending-Active Hybrid Structures

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Computation in Architecture
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CONTENT

ABSTRACT

Dynamic needs of modern society call for architecture that is responsive and deals with urban densification. Designing such structures poses a number of architectural, structural and social constraints. The objective of this thesis is to establish a homogenous design framework for responsive architecture in the context of public events using transformable bending-active hybrid structures.

The project will challenge a conventional linear design workflow in architecture through 4 objectives - examining form language and spatial expressions of textile hybrids, investigating their relation to each other and the context of public domain, evaluating the structural and architectural performance of hybrid structures and designing a method for adaptable hybrid systems.

While the focal point of this investigation is a workflow to design for urban densification and adaptable design, the proposed methods will present novel aesthetics of kinetic structures, it will probe alternative ways of understanding needs and functions of everyday spaces and it will contribute towards building a system of tools for such architecture to be applied on a large scale.

Figure 1. My physical prototype of hybrid structures, CITA, 2019.

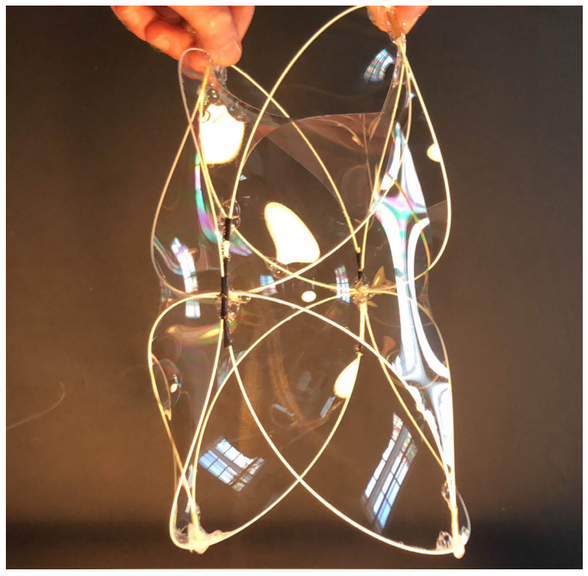


Figure 2. Own work from previous workshops and studio projects, CITAstudio, 2018-2019.

PROLOGUE

This thesis project is based on the knowledge acquired from previous investigations into kinetic textiles and hybrid structures as well as their design process using computational tools in the context of responsive architecture.

My work within the last year spans from designing the textile on the material scale using generative pattern making tools to fabricating large scale form-active hybrid prototypes and exploring their relation to the inhabitant of the space. In my most recent project I investigate an idea of a dialog in the context of space and its user, both architecturally and socially, using lightweight textile systems and digital simulation tools to speculate possible design outcomes.

These projects allowed me to recognize vast potentials of hybrid systems in terms of their structural capabilities when used along with bending-active elements as well as their dynamic spatial outcomes and novel aesthetics that come with it.

Therefore I am curious to challenge the nature of textile hybrids within a project that studies a coherent design methodology of such systems and investigates their feasibility in the framework of responsive architecture.

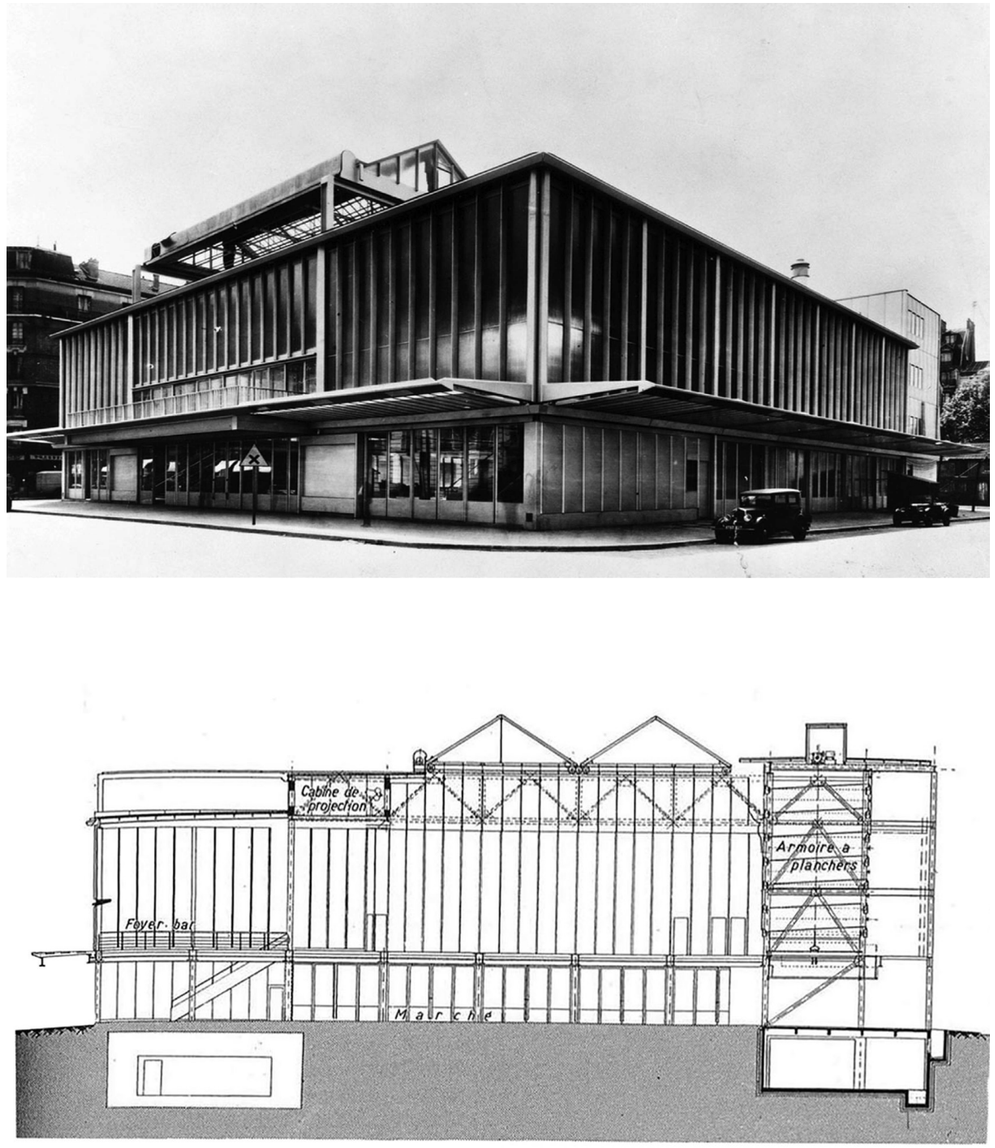


Figure 3. Maison du Peuple de Clichy by architects Eugène Beaudouin, Marcel Lods, 1939. During day time the building would function as a market, and during the night it would transform into a cinema.

TEMPORAL DENSIFICATION

Increase in population, longevity of life and moving from rural areas causes wide city expansion. This has negative impacts on environment, biodiversity and urban overcrowding. One of the strategies to deal with city densification could be examined in a context of responsive architecture. Responsive architecture, by its nature, raises an opportunity to be fully dynamic, meaning that it does not have to have a final state and can be manipulated or adjusted to suit the needs of those who use it.

The inspiration for the project derives from Maison du Peuple which arguably is one of the earliest modern examples of flexible architecture. The building accommodates two programmes in a single location, which allows for densification in the urban context in terms of time more than it does in terms of space. It treats densification as a temporal issue and not spatial.

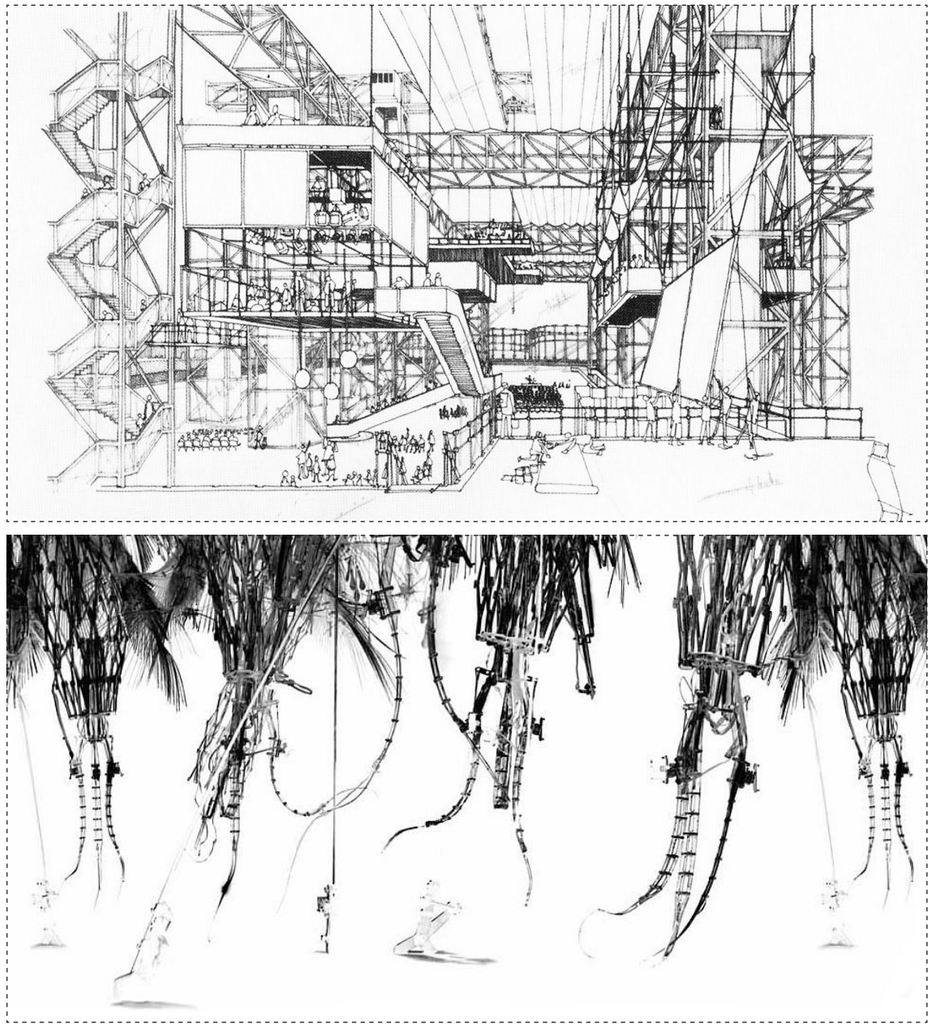


Figure 4. Top: Fun Palace by Cedric Price, 1961.
Bottom: Hylozoic Ground, experimental architecture by Philip Beesley, 2010.

ARCHITECTURE AS SOCIALLY INTERACTIVE MACHINE

Cybernetics, and the idea of a system with a feedback loop and its relationships between the elements, acts as a foundation for the concept of this project. Fun Palace by Cedric Price and work of Philip Beesley are prime references when talking about computational thinking for perceiving architecture as an environmental, social and cultural device.

The basic concept of responsive architecture is to adapt according to predefined rules. The connection between the system and its user is binary and unidirectional. Cybernetics proposes a communication in a form of a dialog, where the system treats a user as a passive element, being observed and evaluated by the architecture, and as an active one, making conscious decisions and informing the system itself.

THEORY

The proposed methodology can be split into two: theoretical and computational parts. The former analyses the events in the context of public space and produces guidelines for the concept of transformable structures. Understanding key demands and boundaries of architectural and spatial qualities required to host various events will produce initial design inputs and contribute towards building an appropriate concept proposition.

COMPUTATION

The latter employs different tools of computation to generate, investigate, evaluate and finally design responsive architecture, both in terms of individual elements and collections of them. The measure of success will be decided by the presence of all elements in the final system design and a coherent connection between them.

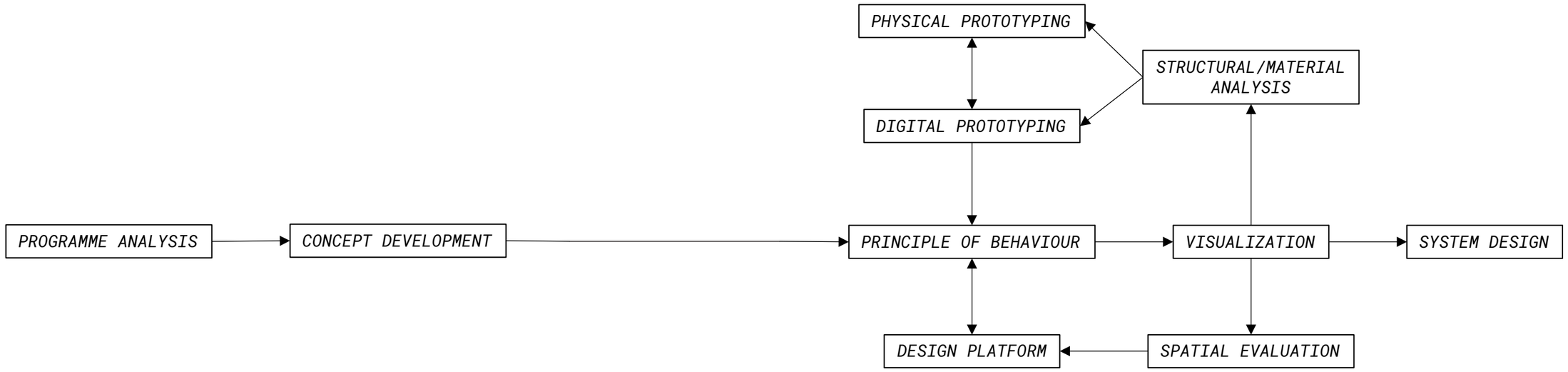


Figure 5. Proposed methodology for thesis project.

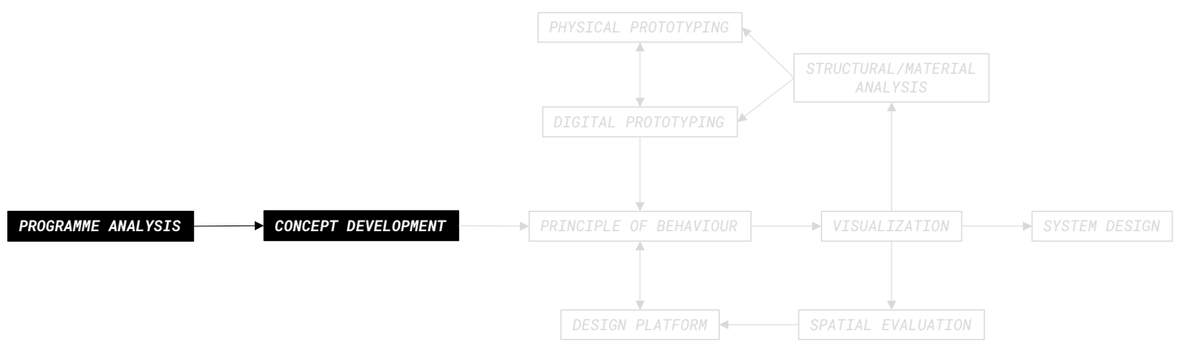
Figure 6. Chosen site for event analysis in Meatpacking District, Copenhagen.

SITE AS A PLACEHOLDER

A public square in Meatpacking District, Copenhagen will be used as a site and any further analysis will be applied to the scale and specifics of this particular area. In terms of disparity, the square is surrounded by and is a part of an active social life, both during day and night times. Moreover, the space functions as a parking lot for adjacent buildings during certain hours, therefore is a great case for study of transformable structures.

On the other hand, the site is only a placeholder and the ultimate goal is to have a system that is site-independent and could be adapted to various scenarios.

Figure 7. Food festival in Meatpacking District, Copenhagen, 2016.



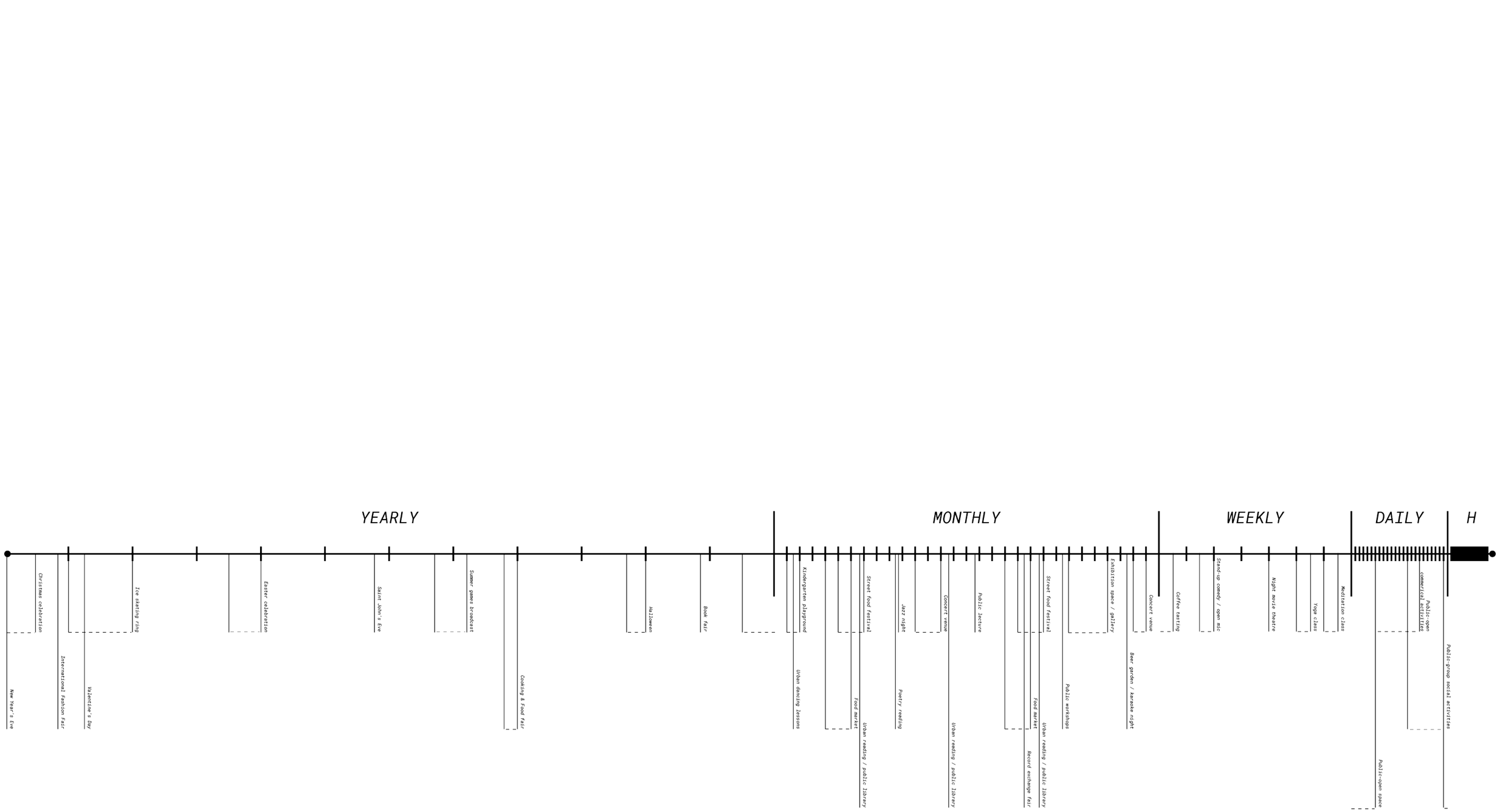


Figure 8. A timeline of public events in the chosen site.

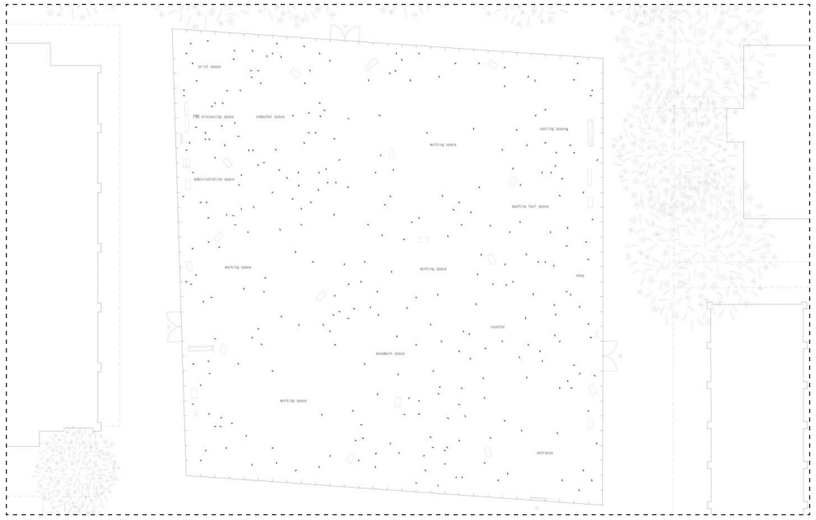


Figure 9. Kanagawa Institute of Technology by Junya Ishigami, 2010.

GRID AS AN ORGANIZER

To arrange structures within the site, I use a hexagonal grid. The hexagon is the shape which covers and creates the best open area while minimizing the boundary. It is only used as an organizer and not as a design driver. Similar example can be seen in work of Ishigami where the columns are following certain grid rules yet they appear to be scattered almost randomly.

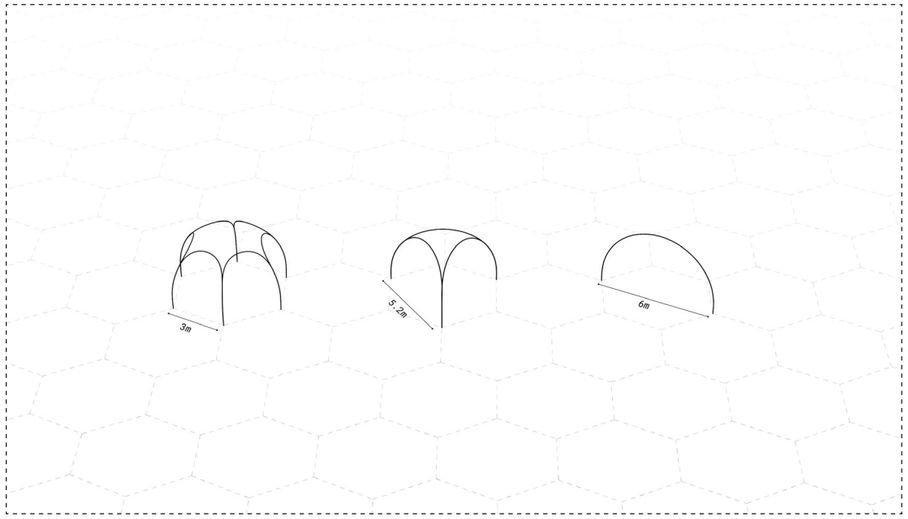
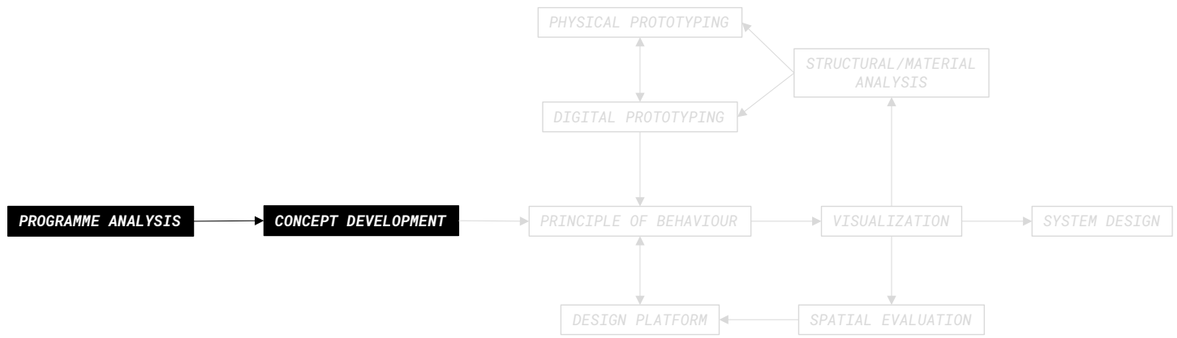
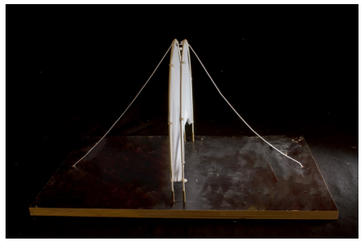
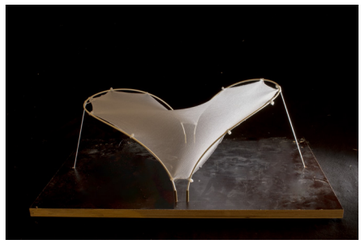


Figure 10. Concept diagram explaining the use of grid to anchor structures within the site.

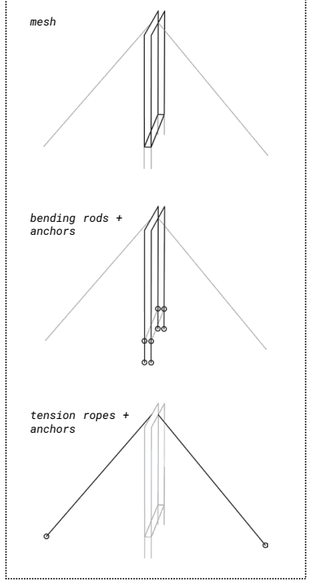


PHYSICAL PROTOTYPE

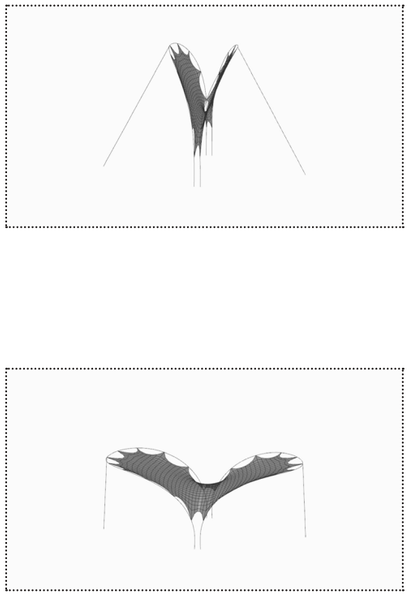




KANGAROO INPUT



RELAXED GEOMETRY



INDIVIDUAL

COLLECTION

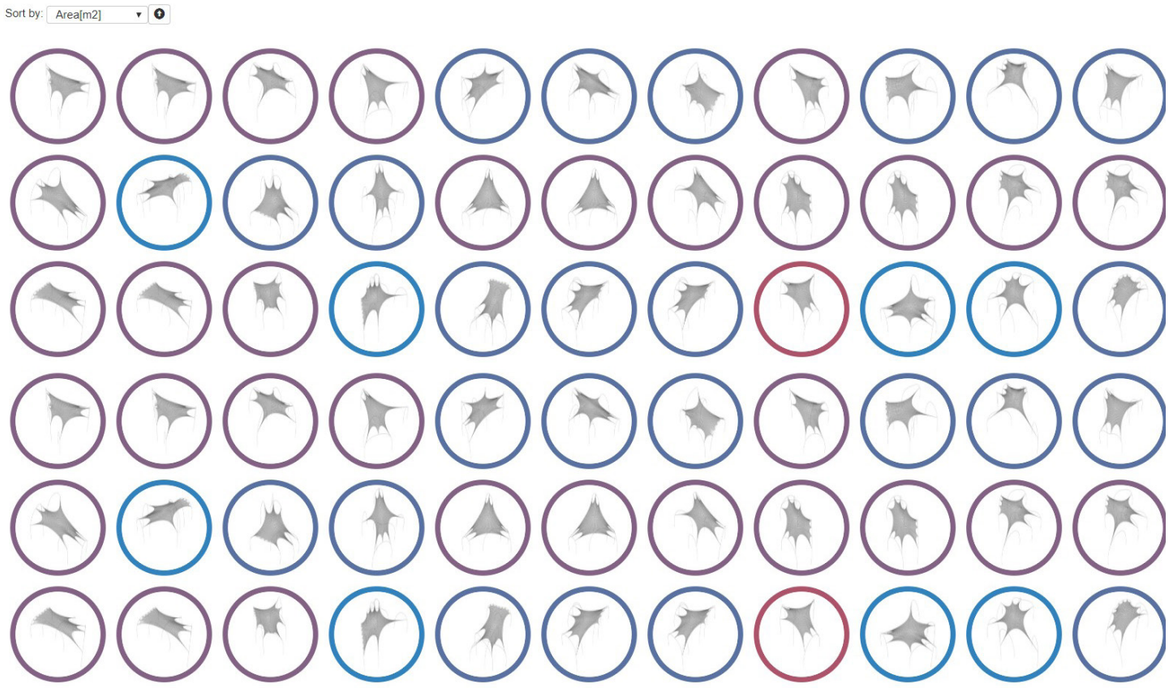
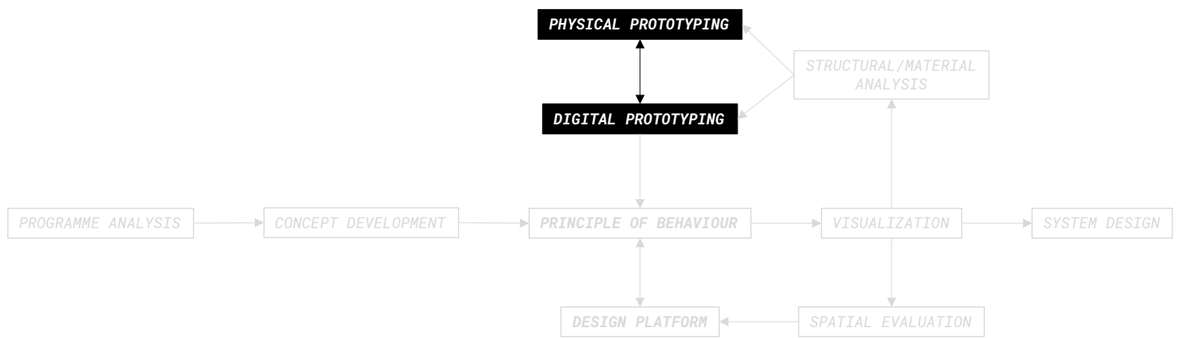
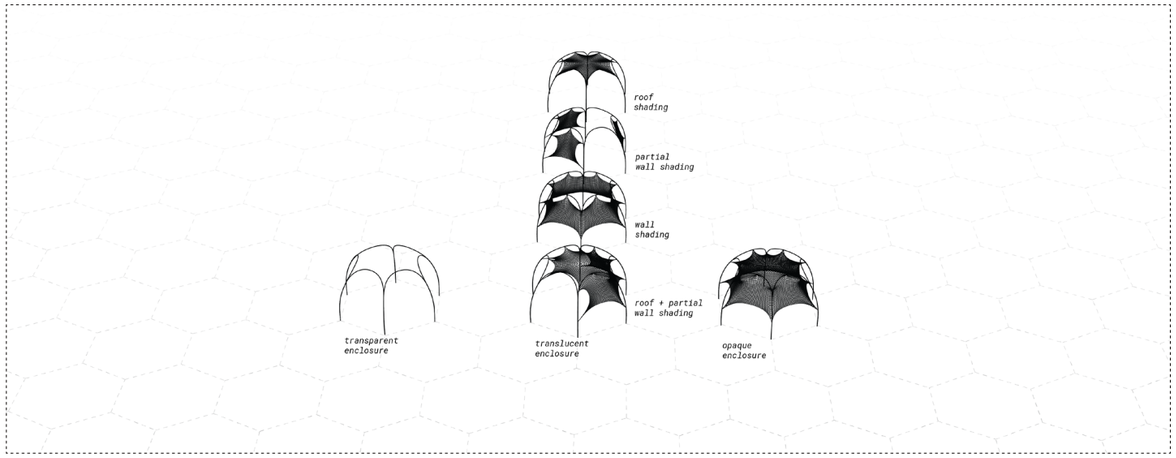


Figure 11. Top: Translation from physical prototypes to digital using Kangaroo physics engine. Bottom: Permutations of spatial setups using recursive loops to generate them.

COMPUTATION AS MEANS TO GENERATE

Digital prototyping and recursive design loops will be primary tools for generating unique spatial setups. Intriguing or instinctively successful results will be recreated as physical prototypes and will feed back into the digital with more calibrated parameters.





INDIVIDUAL

COLLECTION

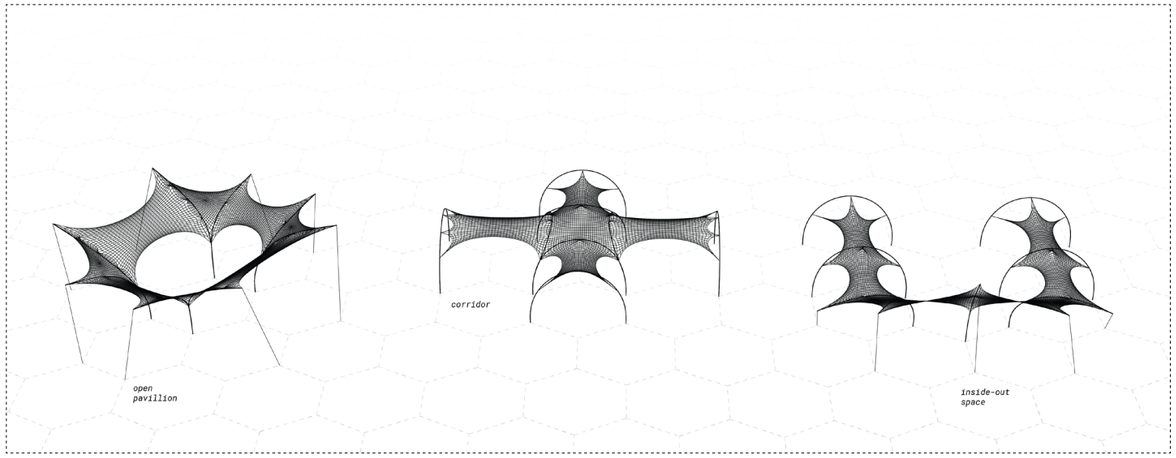


Figure 12. Top: Investigation into various membrane setups and their relation to light. Bottom: Exploring typologies of hybrid structures while using repeating elements.

COMPUTATION AS MEANS TO INVESTIGATE

Successful responsive structures consist of many unique characteristics. For my thesis project, I have identified 3 key categories and I will first examine them separately in an attempt to connect them later to propose a comprehensive design.

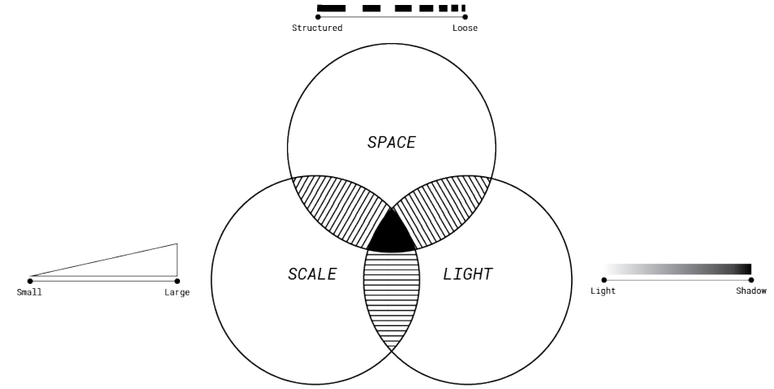
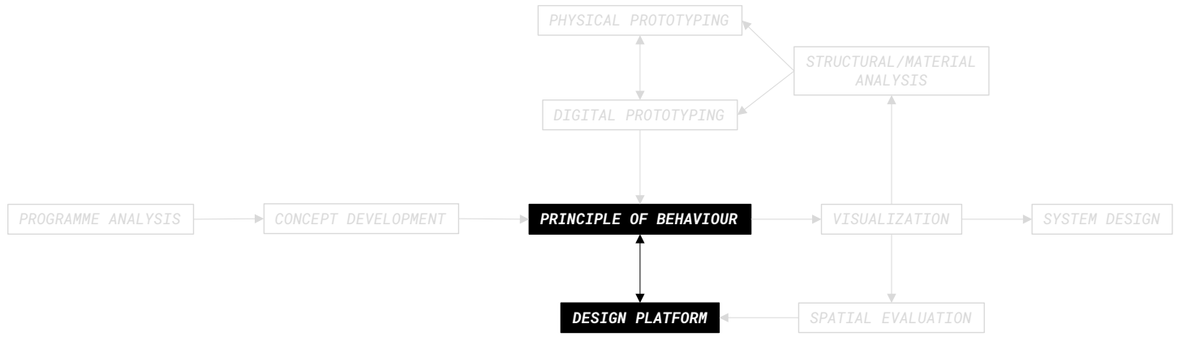
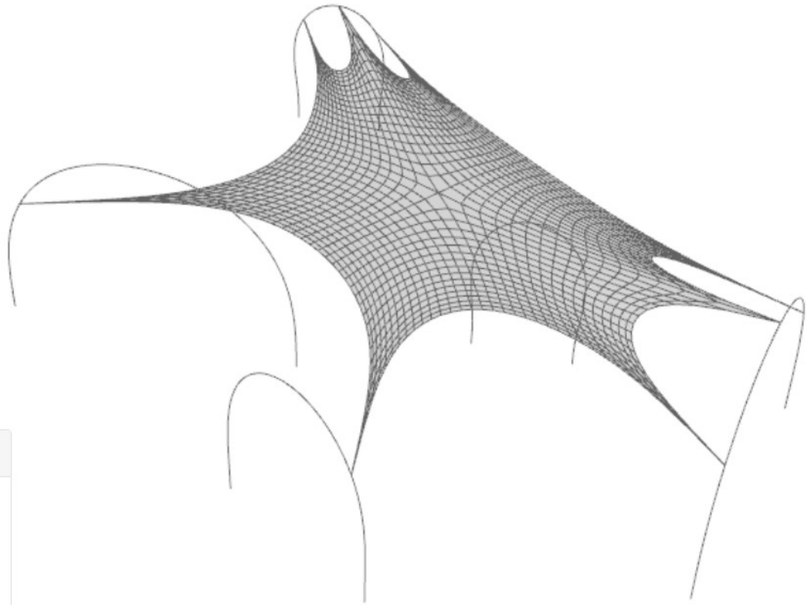


Figure 13. Logic diagram of key design vectors for hybrid structures.





Attributes

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Volume[m3] : 2077.576703
RodLength[m] : 68.044662
Rating : 0

INDIVIDUAL

COLLECTION

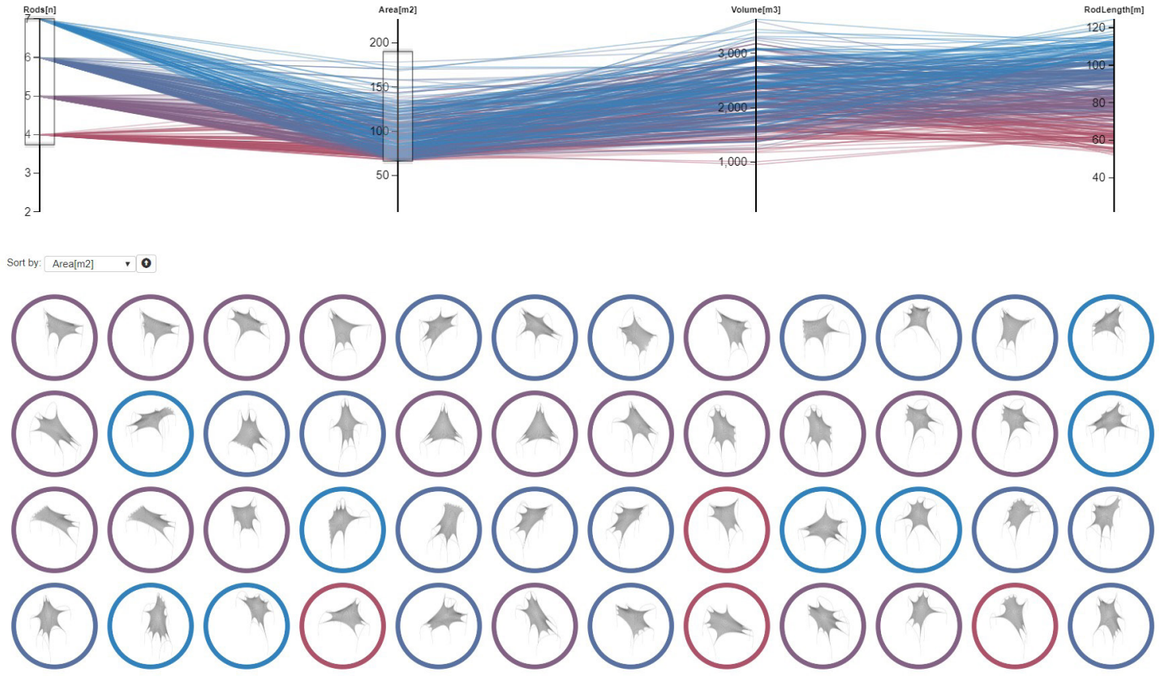


Figure 14. Top: Evaluating individual elements in terms of material & structural performance.. Bottom: Evaluating & organizing clusters of structures and filtering out successful ones.

COMPUTATION AS MEANS TO EVALUATE

Relating to previous parts of the process, evaluation is split into two - evaluating discrete elements, for their structural and material performance; and evaluating clusters of elements, for their organizational & spatial parameters.

The goal of this analysis is to recognize applicable permutations generated earlier and feed them back into generative and investigation parts of the design. The most successful iterations will build a library of structures that will be used for a system design in the final step.

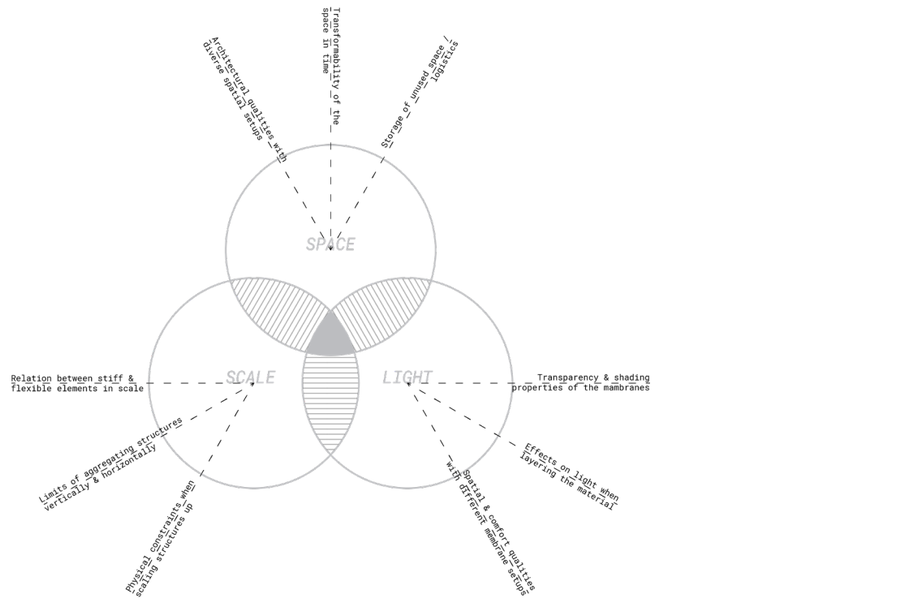
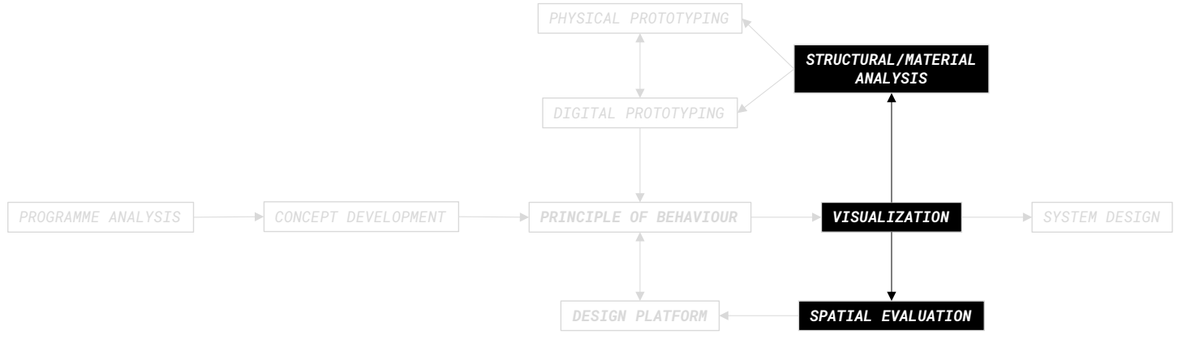
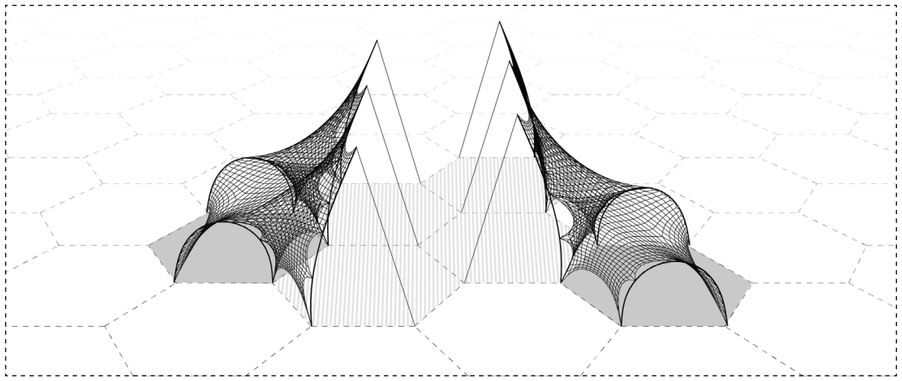
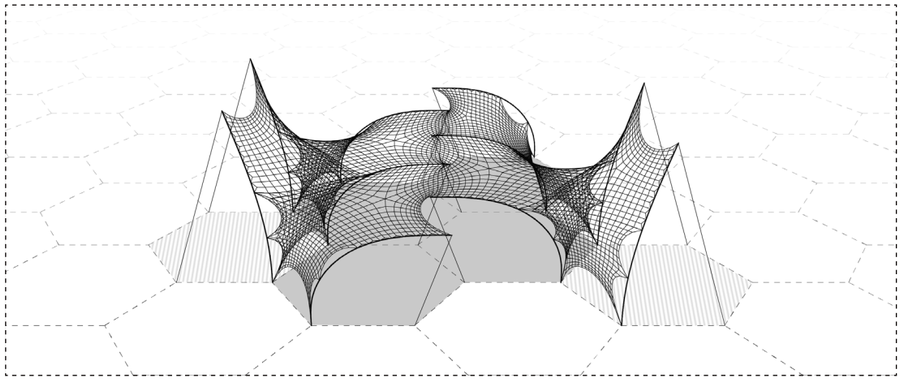


Figure 15. Evaluation vectors for each of the design category.







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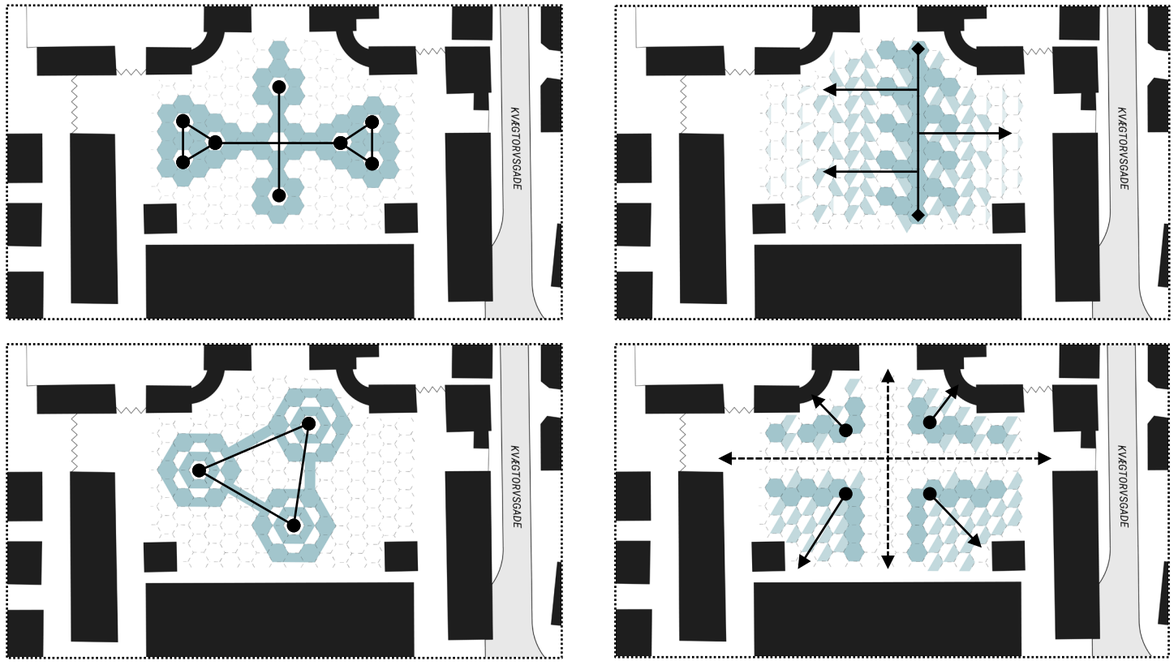

Figure 16. Top: Design based on various architectural qualities of the space.
Bottom: Meta design on-site using vectors and axis instead of scattering individual elements.

COMPUTATION AS MEANS TO DESIGN

Design remains an important part throughout all stages of the process. Designing unique setups for specific architectural qualities will be integrated in the early steps, and designing clusters for specific architectural programmes & events will address meta issues of the project.

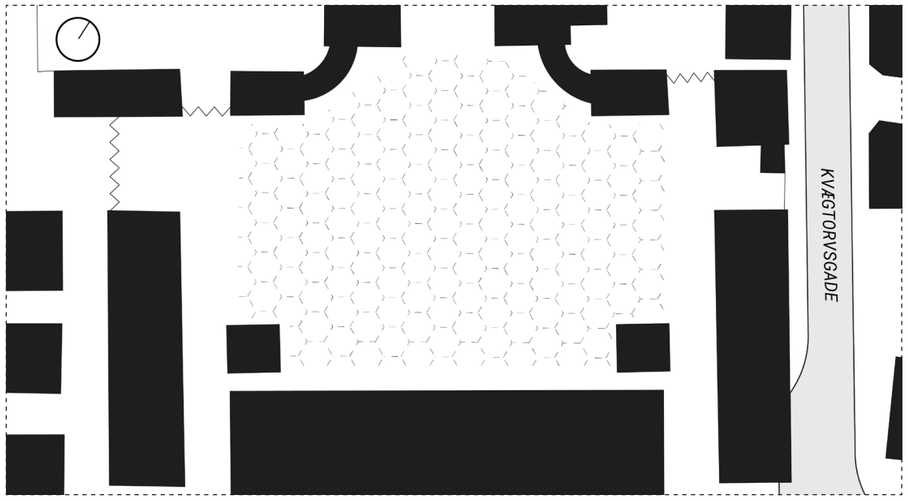

Figure 17. Site plan with an overlaid hexagonal grid.

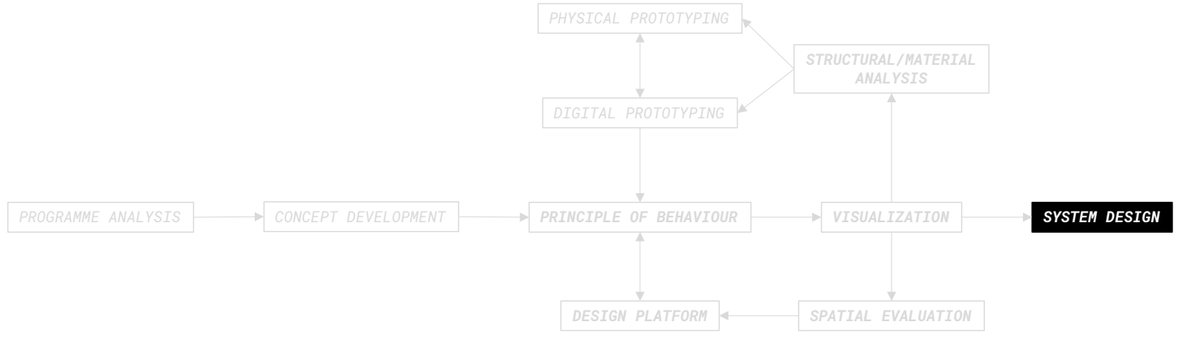

Figure 18. UN Sustainable Development Goals, sustainabledevelopment.un.org, 2019.

SUSTAINABLE DEVELOPMENT GOALS

Adaptable structures will allow to accomodate diverse events and programmes within the same location while employing a minimal amount of additional resources, thus creating a sustainable solution for hosting public events in dense city areas. By building tools for more effective infrastructures and employing embedded energy of the material, the structures are capable of achieving great dynamic spatial outcomes and working in systems just as well as individual elements. This can be related to UN Sustainability Goals 9 & 11.

Dealing with urban densification using lightweight structures of low material intensity makes them cheaper and have smaller environmental impact. In addition, a modular system with a limited amount of discrete elements promotes reusing and responsible production. This can be related to UN Sustainability Goal 12.

TIMELINE & DELIVERABLES

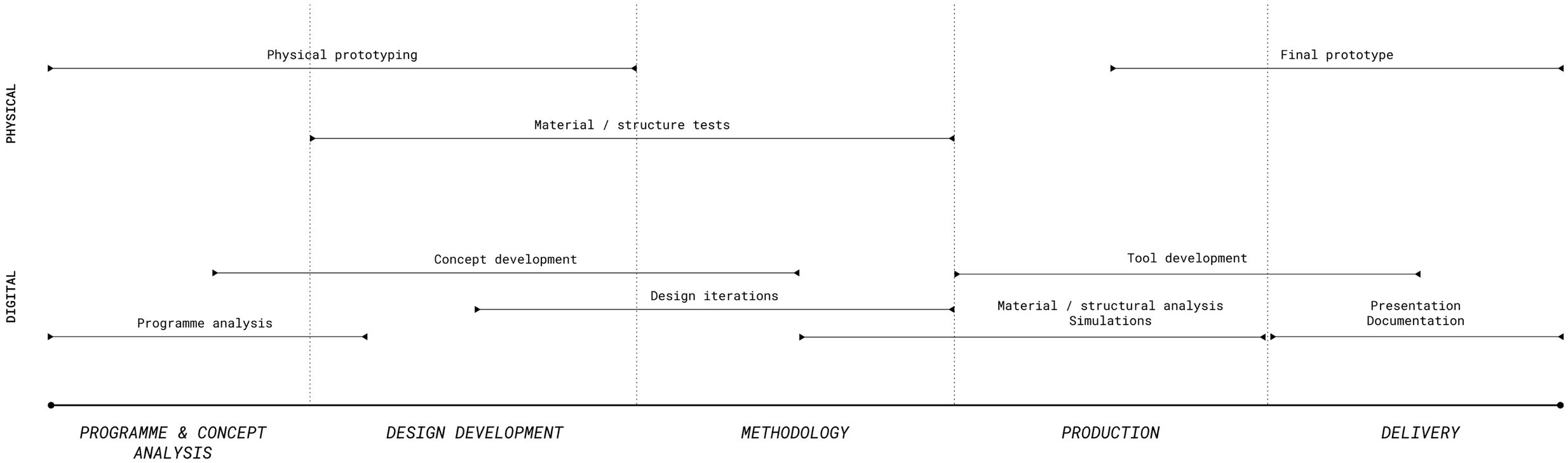

Figure 19. Timeline & deliverables.